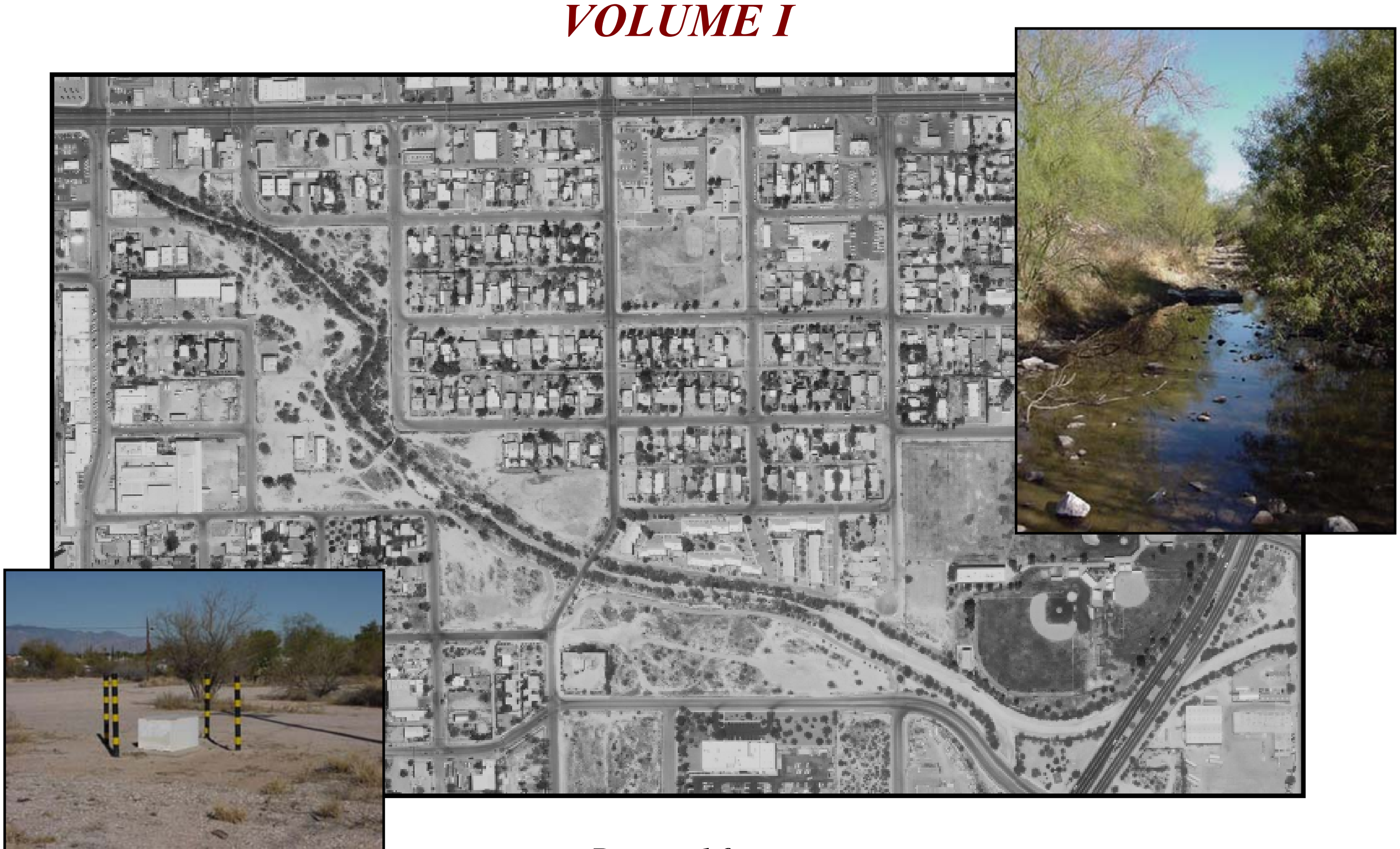
PHASE II ENVIRONMENTAL SITE ASSESSMENT

ARROYO CHICO MULTI-USE PROJECT
TUCSON, ARIZONA

VOLUME I



Prepared for:

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FINAL REPORT
PHASE II ENVIRONMENTAL SITE ASSESSMENT

ARROYO CHICO MULTI-USE PROJECT
TUCSON, ARIZONA

Prepared for:

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April 1, 2002
File No. 10.197003.02

Ms. Karen Masbruch
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P.O. Box 27210
Tucson, Arizona 85726-7210

Subject: Final Report
Phase II Environmental Site Assessment
Arroyo Chico Multi-Use Project
Tucson, Arizona

Dear Karen:

Enclosed please find our Final Report for the Phase II Environmental Site Assessment for the above-referenced project.

SCS Engineers appreciates the opportunity to assist you with this project. Should you have any questions regarding this report, please contact Pat at (520) 696-1617 or Brad at (602) 840-2596.

Sincerely,

Pat M. Hart

Patricia M. Hartshorne, R.G.
Senior Project Geologist

Brad Johnston

Bradley F. Johnston, P.G.
Vice President
SCS ENGINEERS

cc: Zbig Osmolski, Pima County Department of Transportation and Flood Control District

Attachments

PMH/BFJ:pmh
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CONTENTS

CONTENTS

CONTENTS

Section **Page**

CONTENTS

CONTENTS

FIGURES

CONTENTS

EXECUTIVE SUMMARY

The City of Tucson (COT) and Pima County (County) retained SCS Engineers (SCS) to perform a Phase II Environmental Site Assessment (ESA) for the Arroyo Chico Multi-Use Project. The project area encompasses unimproved properties situated in and adjacent to the Arroyo Chico, located between Park Avenue to the west and Kino Parkway to the east. The subject site parcels include unimproved commercial and residential zoned properties. The intended future uses of the project site are multi-use flood control detention basins and public park space. The following discussion summarizes the results of the Phase II ESA investigation.

APARTMENT BUILDINGS

The Arroyo Chico Apartment complex was surveyed for the presence of asbestos-containing materials (ACMs) and lead-based paint (LBP) in the event that partial or full demolition of the buildings might be required. A total of 81 samples were analyzed for asbestos, and 16 paint chip samples were analyzed for lead.

Asbestos was detected in painted and troweled wall and ceiling texture, drywall joint compound, vinyl floor tiles and mastic, and paper duct tape. Asbestos is assumed to be present in roofing materials and possible cement-asbestos flues penetrating the roof. The site was occupied and many areas were not accessible at the time of the assessment; therefore, not all portions of the buildings could be surveyed. Repair and/or removal of ACMs should only be performed by qualified individuals utilizing appropriate control methods.

A total of 16 paint chip samples were collected from interior paints, exterior wall paints, painted foundations, and other painted surfaces. Lead was detected at concentrations above the laboratory detection limit of 0.003 percent by weight in the samples of exterior paint, foundation paint, and paint on cabinets inside one unit. These results do not indicate that the overall waste stream that would be generated by demolition of the apartments would be hazardous waste based on the toxicity characteristic for lead.

SHALLOW SOIL ASSESSMENT

Soil samples were collected from areas of potential concern on the site. Sampling depths ranged from ground surface to 40 feet below ground surface (bgs). Twenty-nine soil samples were analyzed for volatile organic compounds (VOCs), 26 soil samples were analyzed for semi-VOCs, two soil samples were analyzed for tritium, two soil samples were analyzed for polychlorinated biphenyls (PCBs), and three soil samples were analyzed for geotechnical parameters (bulk density, permeability, porosity, percent moisture, and total organic carbon).

No staining or odors were observed and laboratory results did not identify detectable concentrations of VOCs or semi-VOCs in these samples (or PCBs in the two samples), with the exception of the following. One sample, collected from the surface of the lower sidewall of the arroyo, contained very low concentrations of fluoranthene and pyrene, which are components of diesel fuel. Detected concentrations were over six orders of magnitude less than current Arizona Department of Environmental Quality (ADEQ) Residential Soil Remediation Levels (SRLs).

A concrete vault structure located at 1041 East Miles Street was identified as a potential environmental concern in the project area. A search of COT building records identified the structure as a sand and grease interceptor connected to the public sewer system. The facility at this location was formerly occupied by an automobile washing and detailing business. At the time of the site investigation, the property was occupied by a business that manufactured cast concrete landscaping features. Because the vault was identified as an interceptor that discharges to the sewer system, it is not likely to be the source of significant environmental impact to soils in the Arroyo Chico project area.

INITIAL STORMWATER INFILTRATION INVESTIGATION

A stormwater infiltration assessment (percolation testing) was performed as specified by the COT and County in order to characterize the subsurface profile and determine the potential infiltration characteristics of the subsurface materials at specific locations across the site at the proposed stormwater detention basins. Maxim Technologies, Inc. (Maxim) was retained to perform percolation tests at six locations within the Arroyo Chico project area to evaluate the infiltration characteristics of the subsurface materials beneath the low-permeability caliche layer that is exposed at the base of the arroyo.

Percolation rates observed during falling-head tests in the test borings ranged from 4.3 feet per day to 62.0 feet per day, depending on the test location and the amount of hydraulic head (five or ten feet) applied to the test. The slowest percolation rates (4.3 and 9.1 feet per day under 5 and 10 feet of head, respectively) were observed in the test boring closest to the Mission Linen property, which is located across Fremont Avenue from the site. Using very conservative assumptions, Maxim estimated that the potential depth of saturation beneath the proposed basins ranged from 48 to 61 feet bgs for a 36-hour hold time, 32 to 56 feet for a 12-hour hold time, and 13 to 45 feet for a 6-hour hold time. Maxim recommended lining the bottom of the proposed basins if the goal was to prevent infiltration from occurring.

However, infiltration rates over the entire proposed basin area would likely be much less due to factors including (but not limited to) air entrainment, evapotranspiration, siltation, and compaction. In addition, this methodology assumed that nearly all the water percolated in a vertical direction; however, the methodology could not completely eliminate the effects of lateral percolation. Because the methodology did not account for the above factors, the obtained results were assumed to be very conservative.

ADDITIONAL SOILS INVESTIGATION AND STORMWATER INFILTRATION ASSESSMENT

By request of the COT and County, an additional soils investigation and infiltration assessment was performed to clarify the initial infiltration results and to provide additional characterization of the soil profile and the extent of caliche within the channel and proposed basin areas. Errol L. Montgomery & Associates (Montgomery) excavated eight infiltration test pits, performed seven double-ring infiltrometer tests and three “small basin” percolation tests within the channel, excavated ten backhoe trenches within the channel, monitored infiltration of ponded water in seven naturally occurring depressions in the well-lithified caliche in the channel, and drilled six soil borings adjacent to the channel.

Stabilized infiltration rates for the infiltrometer tests ranged from 1.4 to 2 feet per day in three of the test pits and from 17 to 39 feet per day in four of the test pits. The lower infiltration rates were interpreted by Montgomery to be due to weak to moderate lithification of the sediments. The small basin tests obtained infiltration rates of 3 to 5 feet per day. Significant lateral migration was observed at one of the test pits, with a saturated depth in soils beneath the test area of only 3 to 4 inches following the testing. Infiltration rates measured at the naturally occurring depressions in the lithified caliche in the channel ranged from 0.04 to 0.4 feet per day.

Montgomery estimated that the representative average infiltration capacity for the Arroyo Chico site would be between 3 to 10 feet per day more or less, depending on the continuity of moderately- to well-lithified sediments. Dividing this average infiltration capacity by a fillable porosity of 20 percent, the projected depth of wetting front movement would be 15 to 50 feet per day, or 22 to 75 feet for the maximum 36-hour detention time for the stormwater. Montgomery recommended lining the bottom of the proposed basins to ensure that significant infiltration would not occur.

Limitations identified for the use of this data included the small scale of the tests versus the size of the proposed basins, the observation of lateral flow during some of the infiltration tests, and lack of information regarding the continuity of moderately- to well-lithified sediments beneath the basins. The tests assumed a maximum predicted depth of water for a full 36 hours, whereas most storm events would result in smaller volumes of water stored in the proposed basins over shorter periods of time. The testing also did not account for repeated basin-filling events. In addition, it is likely that fine-grained sediments and organic materials would settle out of stormwater and accumulate on the basin floors after several filling cycles. Infiltration capacity could be greatly reduced due to the accumulation of this surface "skin."

INITIAL GROUNDWATER ASSESSMENT

Two pairs of nested groundwater monitoring wells (WR-345 and WR-347) were installed on COT property at locations reviewed by ADEQ to evaluate groundwater quality concerns associated with the Park-Euclid Water Quality Assurance Revolving Fund (WQARF) site, groundwater gradient, and flow direction beneath the proposed detention basins. The proposed basins include three separate basins situated generally along the axis of the Arroyo Chico wash, with the western basin (referred to as Basin 1) located across the street from the Mission Linen property.

Each nested well location contains a pair of wells completed at two intervals to evaluate the perched aquifer (depth to groundwater generally 96 feet bgs) and the regional aquifer (depth to groundwater generally 200 feet bgs). One of these well locations (WR-347) was placed at the western edge of the proposed western Basin 1 (between Mission Linen and the basin) and the other well location (WR-345) was placed on the opposite (northeast) side of Basin 1.

One groundwater sampling event was performed for the nested wells in February 1998. This sampling event detected tetrachloroethene (PCE), naphthalene, and bis (2-ethylhexyl) phthalate. PCE and naphthalene are likely associated with the solvent and diesel fuel impacts that have been detected at Mission Linen, but phthalates are typically related to plastic compounds and may be associated with drilling or sampling procedures.

Laboratory analytical results indicated that the perched aquifer well at the western edge of the proposed Basin 1 (across the street from the Mission Linen property) contained PCE at a concentration of 34 µg/L, which exceeds the Aquifer Water Quality Standard (AWQS) of 5 µg/L. This well also contained naphthalene and bis (2-ethylhexyl) phthalate at low concentrations. The perched aquifer well northeast of the proposed Basin 1 did not contain PCE, but it did contain phthalate at lower concentrations. The regional aquifer well at the western edge of the proposed Basin 1 contained a very low concentration of phthalate, and the regional aquifer well northeast of the basin contained low concentrations of PCE (2.9 µg/L, which is below the AWQS).

Seven soil samples were collected during drilling of the well borings; these samples were collected at depths ranging from 70 to 110 feet bgs. Laboratory analysis of these soil samples did not identify the presence of analytes exceeding laboratory reporting limits.

Based on groundwater level measurements collected from the Arroyo Chico and Mission Linen monitoring wells in 1998, the direction of groundwater flow in both the perched and regional aquifers was to the northeast. The groundwater gradient was variable across the project area, but averaged approximately 0.006 feet per foot.

RISK ASSESSMENT

Based on the results of the shallow soil assessment, soil contamination was not identified on the Arroyo Chico site, so risks associated with soil contamination are not anticipated. There are no on-site drinking water wells or other potential pathways by which persons on the site could be exposed to contaminated groundwater. Therefore, contamination detected in groundwater beneath the site should not present health risks to persons occupying the site. However, if groundwater contamination were to continue to migrate from the Arroyo Chico monitoring well locations to off-site drinking water wells, an exposure pathway could be completed, and health risks could exist for those obtaining drinking water from the wells.

A preliminary, screening-level groundwater modeling risk assessment was performed for the site. This risk assessment indicated that the possibility exists for groundwater contamination detected at the Arroyo Chico and Mission Linen monitoring wells to potentially impact potable water wells to the north. This assessment was based on very conservative assumptions, and therefore overestimates the likelihood that contamination may reach these wells. Due to the preliminary nature of this modeling effort, potential health effects at these potable water wells were not evaluated.

ADDITIONAL GROUNDWATER ASSESSMENTS

Based on the results of the two stormwater infiltration assessments, the COT and County requested additional investigation of groundwater characteristics to provide more information on the potential for infiltration of stormwater at the site. Tasks included sampling and analysis of groundwater for VOCs, sampling and analysis of groundwater and surface water to perform tritium age-dating, installation and continuous logging of groundwater levels using electronic water level indicators (transducers) in both the perched and regional aquifers, collection of information for predictive modeling, and preparation of technical memoranda documenting the investigations.

Groundwater Sampling and Analysis

Groundwater samples were collected and analyzed from the perched and regional aquifer wells located at WR-347. PCE (160 µg/L), acenaphthene (9.1 µg/L), and bis (2-ethylhexyl) phthalate (45 µg/L) were detected in the groundwater sample from the perched aquifer well (WR-347A) and bis (2-ethylhexyl) phthalate (7.7 µg/L) was detected in the groundwater sample from the regional aquifer well (WR-347B). The concentration of PCE detected in the sample from the perched aquifer well exceeded the AWQS of 5 µg/L. No AWQS for acenaphthene and bis (2-ethylhexyl) phthalate have been established. The Park-Euclid WQARF site is the likely source of the contaminants detected in groundwater samples collected from the subject site wells.

Tritium Age Dating

Tritium age dating was performed for one surface water sample from the Arroyo Chico and groundwater samples from wells WR-347A and WR-347B. The laboratory analytical results were 12.6 Tritium Units (TU) for the sample from WR-347A, 0.05 TU (below the laboratory detection limit of 0.1 TU) for the sample from WR-347B, and 4.12 TU for the surface water sample. The results of the tritium age-dating of the perched aquifer, regional aquifer, and surface water at the project site indicate that the regional aquifer contains groundwater that is at least 50 years old, groundwater in the perched aquifer exhibits an average age of at least 10 years (and less than 30 years), and the two aquifer systems are not in hydraulic communication. Releases of tritium from a facility in the site area during the 1970s could cause the actual age of the perched groundwater to be less than the calculated minimum age of 10 years.

Monitoring of Groundwater Levels

Continuous monitoring of groundwater elevations in perched aquifer well WR-347A and regional aquifer well WR-347B was performed using electronic water level indicators (transducers) from December 10, 1999 through July 28, 2000 at 15-minute intervals. Cyclical fluctuations and a general downward trend were recorded for the water elevations of both the perched and regional aquifer wells. An apparent groundwater recharge event was recorded on January 12, 2000 for the perched aquifer well; no other indications of groundwater recharge were recorded for the well. The groundwater elevations in the regional aquifer did not appear to exhibit any response to the apparent recharge events observed in the perched aquifer data.

Because of unknown factors, such as vadose zone antecedent moisture conditions, the area receiving rainfall, and the effects of local lithology on channeling groundwater flow, it is difficult to correlate one rainfall event with a change in water level using this limited data set. Thus, the rate at which precipitation is recharging the aquifer cannot be determined based on the hydrograph data.

Collection and Interpretation of Supporting Data

The Arroyo Chico flows generally west-northwest towards the Santa Cruz River. Two saturated groundwater zones have been identified in the vicinity of the site: a perched aquifer at approximately 96 feet below land surface, and the semi-confined to confined regional aquifer at approximately 200 feet below land surface. The perched aquifer extends south and west of the site, but apparently pinches out less than a mile north of the site. The areal extent and configuration of the pinch-out zone would be expected to control groundwater flow direction, as well as the capacity of the aquifer to maintain a head of water above the aquitard. Groundwater flow in both the perched and regional aquifers in the vicinity of the site is to the northeast. The regional aquifer provides water supply to the City of Tucson, and heavy withdrawal from the University of Arizona (UA) water supply well field north of the site is believed to influence the direction of regional groundwater flow in the site area.

Rainfall and Barometric Pressure Data

Rainfall and barometric pressure data for the Arroyo Chico area, recorded at a weather station located at the UA approximately 0.75 mile directly north of the Arroyo Chico project site, was obtained for the period of investigation. The water level data collected by the transducers placed in the site wells were corrected for the effects of barometric pressure and diurnal fluctuations; the correction for barometric pressure did not fully explain the magnitude of the variations in the water levels. Because the period of hydrograph data was limited, it was difficult to discern a relationship between a specific rainfall event and a groundwater recharge response. However, recharge apparently occurred in the perched aquifer from September

1999 through January 2000, including the January 12 recharge event. It is probable that the rise in the groundwater elevation represents recharge to the perched aquifer by drainage of water from the Arroyo Chico channel.

Other Tucson Area Studies

Other Tucson area studies have reported wetting front migration velocities of 1.9 to 9.0 feet per day for recharge zones similar to the perched aquifer at the site. Isotope studies of recharge in the Rillito River have measured an approximate 2-year travel time through the vadose zone at a rate of approximately 0.18 feet per day. However, hydrograph responses to individual rainfall events were reflected approximately 30 days after a substantial rainfall, possibly attributed to a “piston” pressure flow response, which causes infiltrated water to push downward on water already present in the vadose zone, thus inducing a recharge response at the water table.

Comparison of Site Investigation Data With Other Tucson Area Data

If it is assumed that the approximately 90 feet of vadose zone beneath the Arroyo Chico channel is similar to that beneath the Rillito River channel area, a particle of water could take a minimum of approximately 16 months to reach the water table. However, the “piston” pressure flow response could induce a recharge response in the groundwater levels in as little as 20 days. Using the measured wetting front velocities of 1.9 to 9.0 feet per day observed for other studies performed in the Tucson area, the estimated time for the observed hydrograph response to a recharge event at the site would be within 10 to approximately 48 days.

Comparing these estimated times of travel to rainfall events recorded at the UA weather station, there should have been responses evident on the hydrograph for WR-347A sometime between mid January and early August. No hydrograph responses were identified during the monitoring period. If the general rise in groundwater elevations observed between September 1999 and January 2000 represents a series of discrete “piston” recharge events following the

1999 monsoon season, the January 12, 2000 rise might represent the end of recharge attributable to the monsoon rainfall.

PREDICTIVE GROUNDWATER MODELING

By request of the COT and County, SCS retained Daniel B. Stephens & Associates (DBS&A) to perform predictive groundwater modeling to evaluate the effect of infiltration of stormwater at the locations of the proposed stormwater detention Basin 1. The objectives were to estimate the difference in infiltration for scenarios without the proposed basin (existing conditions) and with the proposed basin (after construction). Tasks performed included compilation and analysis of existing data, development of a conceptual hydrologic model based on the existing data, construction of numerical models, and performance of simulations to quantify potential infiltration.

Information used to establish the hydrogeologic setting for the site area was obtained by reviewing data collected by SCS, Maxim, and Montgomery during the previous work performed for this project investigation and by review of documents at ADEQ for investigations of the Park-Euclid WQARF site. The computer modeling used the computer code HYDRUS-2D, which uses a finite element approach to solve the Richards equation for water flow in variably saturated media, and allows for transient variations in boundary conditions. The modeling profiles were based on an average (or representative) cross section of Basin 1, and boundary conditions used for the simulations included no-flow, variable pressure head (to simulate ponding), and prescribed pressure head boundaries; the lower boundary was the top of the perched aquifer. Hydraulic parameters required for the model input included residual and saturated water contents, saturated hydraulic conductivity, and fitting parameters for the soil-water retention and unsaturated hydraulic conductivity functions, which were derived using the analytical model of van Genuchten. Because there was little to no site-specific data available for the above parameters, these values had to be estimated.

Three separate surface water flow events were simulated for each of the two model scenarios: the 100-year, 10-year, and 2-year flow events. Ponded infiltration into the subsurface soils was simulated during the period of saturated conditions. Each simulation was run for a period of 50 years. Additional simulations were performed to evaluate the sensitivity of the model results to variations in the initial conditions.

The simulations showed that infiltration is consistently greater for the scenarios with the basin in place than for the existing conditions at ratios ranging from 2.8:1 to 3.0:1. Both the basin and existing conditions scenarios show that most of the infiltration occurs in the first 8 hours of each flow event. The scenarios that simulated usage of a low hydraulic conductivity material on the basin floor showed that partially lining the basin could significantly limit infiltration to amounts less than or generally equivalent to the existing infiltration amounts.

DBS&A explicitly stated that the simulations should not be used to estimate wetting front migration rates or vadose zone travel times for depths greater than a few meters, because this arrival time calculation is highly sensitive to modeling assumptions, including the initial conditions (i.e., starting pressure heads or water contents) and unsaturated hydraulic properties, as well as lithologic heterogeneity of the subsurface soils (such as clay lenses). There was insufficient site-specific information that could be used to determine the extent of low-permeability zones (or areas of preferential flow), relatively few soil water content measurements near the Arroyo Chico channel, and no measurements of unsaturated hydraulic properties. Because only the near-surface area will be altered by construction, the travel time will be basically the same for both scenarios given the same volume of water entering the system. According to DBS&A, it was impossible to accurately quantify the overall influence of vegetation on the water balance for the project scenarios because there are no soil parameter data for vegetated areas. Vegetated soils generally have permeabilities an order of magnitude higher than non-vegetated soils due to macropores and other soil structures created by plants.

DISCUSSION OF STORMWATER INFILTRATION, GROUNDWATER ASSESSMENT, AND GROUNDWATER MODELING RESULTS

The results from the infiltration and groundwater modeling investigations discussed in this report are limited by the paucity of site-specific soil and groundwater information, including (but not limited to) the extent of moderately- to well-lithified sediments, soil moisture contents, lithologic heterogeneity, unsaturated hydraulic properties, locations of preferential flow pathlines, and long-term groundwater levels. Actual stormwater infiltration rates over the entire basin area would likely be much less than was calculated due to factors including (but not limited to) air entrainment, evapotranspiration, siltation, and compaction. The collection of additional data would require extensive additional soil and groundwater investigations. Without additional data, the results discussed in this report must be viewed as conservative estimates based on the limited available data.

Limitations for the investigations included the small scale of the infiltration tests versus that of the proposed basins; the very wide range of results for the infiltration rates obtained during the testing (nearly 0 feet per day up to 40 feet per day), which made development of a reasonable average infiltration rate or even a range of rates difficult; lateral flow during infiltration testing, which results in an overestimate of the steady-state infiltration rate; the lack of information regarding the continuity and extent of moderately- to well-lithified sediments and the degree of heterogeneity of sediments beneath the basins; the effect of siltation on the bottom of the basins, which would limit infiltration of stormwater; and assumptions used for the infiltration tests that included a constant maximum depth of water for the full 36-hour period, a single basin-filling event, and saturated conditions. Groundwater modeling is a predictive tool that can only simulate conditions based on input values that are chosen to best represent site conditions. The results for the groundwater modeling simulations are entirely dependent upon the values used for the model input; if there is little site-specific information available, the input values must be estimated, which can result in simulations that may or may not represent actual site conditions.

If the project goal is to keep the net infiltration of water the same for the constructed basins as for the existing site conditions, Maxim, Montgomery, and DBS&A recommended that the bottom of the basins be lined. DBS&A recommends that the basins be lined to the high water level of the 2-year flood event with a reduced permeability material consisting of compacted soil, soil amendments, or synthetic material. The area requiring reduced permeability can also be minimized by altering the footprint of the 2-year flood event using berms or terraces.

SECTION 1
INTRODUCTION

BACKGROUND

The City of Tucson (COT) and Pima County (County) retained SCS Engineers (SCS) to perform a Phase II Environmental Site Assessment (ESA) for the Arroyo Chico Multi-Use Project. The project site encompasses unimproved properties situated in and adjacent to the Arroyo Chico dry wash, located between Park Avenue to the west and Kino Parkway to the east. The intended future uses of the project site are multi-use flood control detention basins and public park space. The location of the site is shown on Figure 1 and the site plan is shown on Figure 2.

AGRA Earth and Environmental Inc. (AGRA) performed a Phase I ESA of the project area in November 1997 for the COT. The United States Army Corps of Engineers (USACE) completed an Environmental Impact Study (EIS) in September 1997. The COT Request For Bid (dated December 17, 1997) identified the following environmental concerns for the site project area:

- There was apparent stained and discolored soil observed in the Arroyo Chico within the site project area. In addition, there were reportedly historic diesel fuel surface releases from an upstream railroad yard that may have entered the site portion of the Arroyo Chico.

- Dry cleaning wastes may have been disposed on unimproved properties east of Fremont Avenue and north of Manlove Street.

- Stained soil was observed on the north bank of the arroyo immediately south of the property at 1028 East Broadway Boulevard. The adjoining property was used for automotive and electric engine maintenance and repair.

- Stained soil and distressed vegetation was identified on a property adjoining a synthetic landscape rock/features production facility at 1041 East Miles Street. A sub-grade concrete vault structure was also identified at this facility. The property at 1041 East Miles Street was previously occupied by an automotive painting and body repair business. The property address was incorrectly identified in the AGRA Phase I Environmental Site Assessment report as 1130 and 1140 East 13th Street.

- There were reported releases of tritium to the atmosphere in the 1970s from a facility at Plumer Avenue and the Arroyo Chico, upstream of the site.

- The project development plans included potential full or partial demolition of an apartment complex at Manlove Street and Highland Avenue (Arroyo Chico Apartments). Due to the age of the structures, asbestos-containing materials (ACMs) and/or lead-based paint (LBP) were potentially present in the apartments.

- The Park-Euclid Water Quality Assurance Revolving Fund (WQARF) site (formerly called Mission Linen) has documented impacts to soil and groundwater by diesel fuel and volatile organic compounds (VOCs). The Mission Linen dry cleaning facility property is located across the street from the site to the west, and could be located hydrogeologically upgradient of the site.

- The infiltration rate of potentially impacted stormwater into the soils beneath the Arroyo Chico had not been assessed.

SCOPE OF WORK

This project was performed for the COT and County under the COT Phase II ESA Consultant Contract No. 971144-02, SCS Proposal Number 10.11097.00 (dated December 24, 1997), SCS Revised Work Plan Number 10.11097.01 (dated January 19, 1998), and scope change documents (dated February 27, 1998 and May 7, 1998). The different tasks performed as part of the original scope of the Phase II investigation are described below.

- ***Task 1:*** A shallow soil assessment was performed to characterize specific areas of surface and shallow soils (less than 15 feet below ground surface) that may have been impacted by surface staining, former diesel fuel surface releases, and potential tritium releases; and deeper soils (up to 40 feet below ground surface) that may have been impacted by reported dry cleaning fluid releases. In addition, SCS reviewed public documents to determine the use and potential environmental concerns associated with the sub-grade concrete vault structure present on the property at 1041 East Miles Street.

- ***Task 2:*** A groundwater assessment was performed, consisting of the installation, development, and sampling of two pairs of nested groundwater monitoring wells on the site. Depth to groundwater measurements were collected from site wells and wells at the Mission Linen property located across the street from the site in order to establish groundwater flow directions for both the perched and regional aquifers at the site.

- ***Task 3:*** The infiltration/recharge characteristics of the proposed detention basin locations were evaluated by performing percolation tests at six locations on the site.

- ***Task 4:*** A pre-demolition asbestos survey and evaluation of the potential presence of LBP was performed for the Arroyo Chico Apartments.

- ***Task 5:*** A human health risk assessment (HRA) was proposed to evaluate the potential human health risks that may be attributable to on-site contamination that may be detected in soil, sediments, and/or groundwater beneath the project area. Because no on-site soil contamination or pathways for on-site groundwater exposure were identified, this task was modified to consist only of screening-level groundwater modeling to evaluate potential off-site migration of groundwater contamination in the perched aquifer.

- ***Task 6:*** Public forums and Mayor and Council meetings were attended in order to present the findings and address questions pertaining to the Phase II Environmental Site Assessment.

SCS performed scheduling, oversight, and documentation of site activities; collected soil, groundwater, and waste characterization samples; reviewed background documents to collect information pertinent to the project; performed depth to groundwater measurements at the site and off-site wells (Mission Linen property); surveyed and collected potential ACM and LBP samples; evaluated results of the investigation; and documented the project activities and findings in this report.

Maxim Technologies, Inc. (Maxim) performed the drilling of the shallow (15-foot and 40-foot) soil borings and the stormwater infiltration testing. Layne Christensen Company (Layne) performed the drilling, completion, and development of the groundwater monitoring wells. Geomechanics Southwest Inc. (GSI) performed purging of the monitoring wells for groundwater sampling. Rick Engineering and the COT performed the survey of the well locations to establish well head elevations and locations. Chemical Transportation, Inc. (CTI) provided roll-off containers, temporary storage, and disposal of soil cuttings and wastewater from the drilling and well construction, development, and sampling activities. Transwest Geochem, Inc. (TGI), Turner Laboratories Inc. (Turner), Aqua Tech Environmental Laboratories, Inc. (ATEL), Maxim, and EMC Laboratories (EMC) provided analytical testing of environmental and geotechnical samples.

ADDITIONS TO ORIGINAL SCOPE OF WORK

Additional percolation testing and meetings were performed by request of the COT and County under SCS Proposal Number 10.04498.02 (second proposal revision and scope change summary dated November 12, 1998). Additional groundwater investigations and analysis of the potential effects of subsurface infiltration from the proposed detention basins were performed under SCS Proposal Number 10.04099.00 (dated July 7, 1999; scope revisions dated October 29, 1999 and May 11, 2000) and SCS Proposal Number 10.090200 (dated November 30, 2000; request for change order dated November 14, 2001). The later scope of work additions were performed under the COT Phase II Environmental Site Assessment Consultant Contract Number 002054-02. Descriptions of the additional work performed are provided below.

- ***Additional Percolation Testing and Meetings:*** Additional meetings were held with the COT and County to discuss infiltration test results. The County requested that additional investigation using double-ring infiltrometer testing be performed to clarify the initial infiltration results. SCS retained Errol L. Montgomery & Associates (Montgomery) to perform double-ring infiltrometer and "small basin" tests within the channel of the Arroyo Chico. In addition, excavation of trenches within the channel and drilling of soil borings provided detailed lithologic characterizations.

- ***Groundwater Age Dating and Sampling:*** The COT and County requested additional investigation of groundwater characteristics to provide more information on the potential for infiltration of stormwater at the site. SCS retained Ms. Kristine Uhlman (formerly with SCS and Water Management Consultants, Inc. [WMCI]) to assist with this investigation. Tasks included sampling and analysis of groundwater for VOCs, sampling and analysis of groundwater and surface water to perform tritium age-dating, installation and continuous logging of groundwater levels using electronic water level indicators (transducers) in both the perched and regional aquifers, and preparation of technical memoranda documenting the investigations.

- ***Predictive Modeling:*** By request of the COT and County, SCS retained Daniel B. Stephens & Associates (DBS&A) to perform predictive groundwater modeling to evaluate the effect of infiltration of stormwater at the locations of the proposed stormwater detention Basin 1. Tasks performed included compilation and analysis of existing data, development of a conceptual hydrologic model based on the existing data, construction of numerical models, and performance of simulations to quantify potential infiltration.

LIMITATIONS

This report has been specifically prepared for the COT and County with regard to the assessment of environmental conditions at the site. The report has been prepared in a manner consistent with the level of care and skill ordinarily exercised by other professional consultants, under similar circumstances at the time the services were performed, in this or similar localities. No other representations, either expressed or implied, and no warranty or guarantee is made as to the professional advice presented herein. SCS assumes no responsibility for the accuracy of information obtained from third-party sources such as regulatory agencies.

Sampling and laboratory analyses of selected suspect hazardous materials, including VOCs, semi-VOCs, polychlorinated biphenyls (PCBs), tritium, ACMs, and LBPs were performed during the site investigation. Sampling of other types of hazardous materials or other types of potential pollutants was not performed as part of this investigation. Although this report may provide conclusions regarding the possibility of recognized environmental conditions specific to this site, positive identification of hazardous substances can be accomplished only through sampling and appropriate laboratory analysis.

The asbestos survey at the Arroyo Chico Apartments focused on potential ACMs that could be considered an economic burden due to their presence in significant quantities and potential hazards for asbestos fiber migration through exposure pathways (for example, human contact with damaged, friable ACMs). Other hazardous materials present (for example, trace metals, radon, hydrocarbons, etc.) or asbestiforms naturally occurring in soils and rock at this site are not typically considered in these surveys.

The ACM and LBP survey reporting and analysis represent a limited characterization of ACMs and LBP within the structures. Not all suspect building materials were sampled within each room or common area where observed. Regardless of the number of areas a material was observed, only a representative number of samples were collected from each material. In addition, no attempt was made to provide a statistical approach to completely characterize all of the asbestos or paint within the structures.

It is possible that additional ACMs or LBP may be present within wall spaces, subfloor areas, plenums, electrical panels, mechanical systems, or other areas that were not accessible during this survey. Prior to and/or during renovation or demolition activities, suspect building materials not characterized during this survey should be sampled and analyzed as appropriate.

It is also possible that additional information exists beyond the scope of this survey regarding ACMs and LBP at this site. Changes in site use and conditions may also occur due to variations in tenant use, remodeling activities, mechanical system repair, economics, or other factors. Additional information that was not available to SCS at the time this survey was conducted, or changes that may occur on the site, may result in a modification to the conclusions and recommendations presented herein. This report is not a legal opinion.

As described herein, the results for the stormwater infiltration assessments and groundwater modeling investigations discussed in this report are limited by the paucity of site-specific soil and groundwater information, including (but not limited to) the extent of moderately- to well-lithified sediments, soil moisture contents, lithologic heterogeneity, unsaturated hydraulic properties, locations of preferential flow pathlines, and long-term groundwater levels. Actual stormwater infiltration rates over the entire basin area would likely be much less than was calculated due to factors including (but not limited to) air entrainment, evapotranspiration, siltation, and compaction. The collection of additional data would require extensive additional soil and groundwater investigations. Without additional data, the results discussed in this report must be viewed as conservative estimates based on the limited available data.

SECTION 2
APARTMENT COMPLEX

OVERVIEW

As part of the overall development of the stormwater detention basins in the project area, plan options included the acquisition of part or all of the Arroyo Chico Apartments located at the southeast corner of Highland Avenue and Manlove Street. In the event that a partial or full demolition of the apartment buildings might be required, a pre-demolition asbestos survey was performed and the presence or absence of LBP was evaluated.

ASBESTOS SURVEY

Overview

The asbestos inspection and sample collection was performed to evaluate the presence of ACMs as required by the National Emission Standards for Hazardous Air Pollutants (NESHAP) prior to demolition or renovation of structures. This survey focused on the identification of ACMs that could be rendered friable during demolition activities. Asbestos Hazard Emergency Response Act (AHERA) methodology for determination of ACM condition and fiber release potential was not applied given this objective. However, as required, an AHERA-certified building inspector (Mr. Bradley F. Johnston, P.G. of SCS, AHERA-Certified Building Inspector/Management Planner, accreditation numbers B8896 and B8926) performed the survey.

Rationale and Methodology

This survey focused on the identification of ACMs that could be rendered friable during demolition activities. Exterior roofing materials were not sampled by request of the COT, and destructive or invasive sampling techniques (necessary to access areas behind walls, beneath floors, and other inaccessible areas) were not employed because the site was fully occupied at the time of the survey. The flooring beneath carpeting was not visually observed or sampled. As such, sampling was not performed in a random or statistically complete manner, and sample collection areas were limited to hidden or low-visibility areas such as behind light fixtures and beneath appliances.

Structures on the site consisted of a group of seven buildings, at least some of which were reported to be approximately 50 years old. SCS was provided access to at least one dwelling unit or common area in each building, and all but one of these dwelling units were occupied by tenants at the time of the survey.

Although materials such as ceiling and wall textures appeared similar in all the buildings, each of the seven buildings was considered a separate homogeneous area for purposes of sampling. At least three bulk samples were collected from each suspect material unless otherwise noted.

Building Material Descriptions

The buildings consisted of seven one- and two-story structures set on concrete slabs with no basements. Exterior walls of the first floor units were painted concrete block, while exterior walls of the second story units were wood framing with wooden siding on the exterior and drywall systems (including gypsum board, joint compound, joint tape, and painted or troweled texture) on the interior.

Interior walls were wood framing and drywall systems. Interior ceilings appeared to be the same drywall system as the walls, with the same painted or troweled texture. The laundry room ceiling contained suspended 2-foot by 4-foot acoustic ceiling panels. Flooring included vinyl tiles, linoleum, and carpet.

Mechanical areas were limited to a small exterior closet attached to each dwelling unit. Metal ductwork was not insulated, but seams on exhaust flues were sealed with paper or plastic duct tape. Water piping was not observed because it was located within interior walls.

<u>Building Material Sampling</u>

Suspect Materials--

A visual survey was performed to identify suspect ACMs. Samples of most of these suspect building materials were then collected. Suspect materials included the following:

- Drywall systems (gypsum board, joint compound, and joint tape);
- Painted or troweled drywall texture (walls and ceiling);
- 2-foot by 4-foot acoustic ceiling panels;
- Possible transite (cement asbestos) flues penetrating the roofs (close-range visual inspection or sampling not performed)
- Exterior asphaltic roofing materials (not sampled);
- Paper duct tape on HVAC equipment in some units;
- Vinyl floor tile (only one bulk sample of each vinyl floor tile type was collected due to limited access); and
- Linoleum (only one bulk sample of each linoleum type was collected due to limited access).

A total of 51 bulk samples were collected from these materials. Some of these samples were subdivided by layers at the analytical laboratory, so that a total of 81 samples were analyzed by the laboratory.

Sample Collection and Analytical Methodology--

Samples were collected by spraying the suspect material with amended water, removing a small portion, and placing the sample into a plastic bag. Bags were labeled with a unique identification number and logged onto the chain of custody form.

Bulk samples were delivered to EMC for analysis by polarized light microscopy (PLM). EMC is fully accredited by the National Voluntary Laboratory Accreditation Program (NVLAP) to perform analysis of bulk samples for asbestos using PLM. Samples containing multiple layers were separated and individually analyzed by EMC. These sample layers are indicated by A, B, and C suffixes on the sample numbers shown on the laboratory report.

Laboratory Analytical Results

Laboratory analytical results are summarized below and the complete laboratory report is provided in Appendix A. The following materials were confirmed as ACMs (greater than one percent asbestos):

- ***Drywall texture:*** Asbestos was detected at a concentration of 2 percent chrysotile asbestos in samples collected from all seven buildings. However, not all texture samples contained asbestos.

- ***Vinyl floor tile:*** Asbestos was detected at a concentration of 10 percent to 15 percent chrysotile asbestos in approximately one-half of the vinyl floor tile samples.

- ***Vinyl floor tile mastic:*** Asbestos was detected at a concentration of 2 percent chrysotile asbestos in approximately one-half of the mastic samples.

- ***Drywall joint compound:*** Asbestos was detected at a concentration of 2 percent chrysotile asbestos in all but one of the joint compound samples.

- ***Paper duct tape:*** Asbestos was detected at a concentration of 50 percent to 70 percent chrysotile asbestos in all paper duct tape samples.

The following materials were assumed to be ACMs:

- ***Possible transite (cement asbestos) flues penetrating the roofs;*** and

- ***Exterior asphaltic roofing materials.***

LEAD-BASED PAINT SURVEY

Rationale and Methodology

This survey focused on the identification of potential LBP in and on the site structures that could affect the management and disposal of demolition debris. Sampling of interior painted surfaces was limited to three samples in three of the dwelling units because the units were occupied. Exterior walls and foundations were accessible on each of the seven buildings, but the roof was not sampled by request of the COT.

Destructive or invasive sampling techniques (necessary to access areas behind walls, beneath floors, and other inaccessible areas) were not employed because the site was fully occupied at the time of the survey. As such, sampling was not performed in a random or statistically complete manner, and sample collection areas were limited to hidden or low-visibility areas and peeling surfaces.

Structures on the site consisted of a group of seven buildings. SCS was provided access to at least one dwelling unit or common area in each building, and all but one of these dwelling units were occupied by tenants at the time of the survey.

Building Paint Descriptions

For the purpose of this survey, it was assumed that there were eight types of paint on the structures. Those paints that were similar in appearance but were on different types of surfaces (for example, cream-colored paint on the concrete foundation and cream-colored paint on the exterior walls) were considered separate types.

Building Paint Sampling

A visual survey was performed to identify as many different types of paint as possible. As previously noted, not all areas were accessible for viewing or sampling because the dwelling units were occupied. Samples were collected from the following paint types:

- Cream paint on exterior walls;
- Tan or cream paint on exterior concrete foundation;
- Brown paint on exterior trim and gates;
- Brown paint on exterior concrete foundation;
- Cream paint on exterior ceiling of walkway in eastern building;
- Cream paint on interior cabinets in Unit 6;
- Cream paint on interior cabinets in Unit 58; and
- Cream paint on interior Maintenance Room walls.

A total of 16 paint chip samples were collected from these materials.

Sample Collection and Analytical Methodology

Samples were collected by scraping an area approximately 1 to 2 inches in diameter and placing the paint chip or chips into a plastic bag. Bags were labeled with a unique identification number and logged onto the chain of custody form. Bulk samples were delivered to EMC for analysis by flame atomic absorption (EPA Method 7420).

Laboratory Analytical Results

Analytical results are summarized below and the complete laboratory report is included in Appendix B. The following paints contained lead at concentrations that exceeded the laboratory detection limit of 0.003 percent by weight:

- ***Cream exterior paint:*** Lead was detected at concentrations ranging from 0.028 percent to 0.415 percent.

- ***Brown exterior paint:*** Lead was detected at concentrations ranging from below detection limit to 0.351 percent.

- ***Cream paint on interior cabinets in Unit 6:*** Lead was detected at a concentration of 0.011 percent.

- ***Tan or cream paint on exterior concrete foundation:*** Lead was detected at a concentration of 0.007 percent.

SECTION 3
SHALLOW SOIL ASSESSMENT

OVERVIEW

The Shallow Soil Assessment consisted of the characterization of soils that may have been impacted by surface staining, former diesel fuel surface releases, potential tritium releases, and reported dry cleaning fluid releases. The scope of services included the drilling of shallow soil borings (15 feet below ground surface), a deeper soil boring (40 feet below ground surface), soil probe and hand auger borings (up to 2 feet below ground surface), and surface sampling.

MOBILIZATION

Meetings

A project kick-off meeting was held on December 31, 1997 to discuss project goals, schedules, methodology, and other items pertinent to the project. In attendance were representatives from the COT, County, Arizona Department of Environmental Quality (ADEQ), and SCS. Following the meeting, based on changes in the scope requested at the kick-off meeting, SCS prepared and forwarded to the COT/County a Revised Work Plan on January 19, 1998. The revised work plan included modifications to the infiltration test methodology and risk assessment methodology, and surface and near surface sampling.

File Review

In order to gather information about the project area in preparation for fieldwork, SCS reviewed reports and files for the Park-Euclid WQARF site (formerly called Mission Linen) at ADEQ in January 1998. SCS reviewed this information, visited the subject site, and prepared site maps showing locations of utilities and proposed sample locations. SCS also prepared a

Site Specific Health and Safety Plan. As part of the Health and Safety Plan, SCS compiled tables containing chemical and health information for contaminants that had been identified in samples as documented in reports for Mission Linen.

Utility Survey

SCS contacted Arizona Blue Stake to provide clearance of underground utilities at locations of planned drilling activities at the site (soil borings, percolation test borings, and monitor well borings). SCS scheduled a utility meet for the site with Blue Stake, marked subsurface boring locations in the field prior to the utility meet, and noted locations of overhead utilities.

The utility meet was held at the site on January 20, 1998; SCS ensured that all utility locators were accounted for either at the meet or by other contact. Before site work began, SCS checked subsurface boring locations in the field for the utility markings. No subsurface utilities were identified in the drilling locations planned for this investigation.

SHALLOW SOIL BORINGS

Rationale

A total of eight shallow soil borings were proposed for the project. These borings were proposed for locations with the highest probability of contamination, based on existing information. Two of the proposed borings were placed in areas of stained soil and distressed vegetation. Three of the proposed borings were placed in the Arroyo Chico drainage channel in order to evaluate the potential impact of reported historic surface flows of diesel fuel through the arroyo. Because vehicular access into the arroyo is currently restricted to the Highland Avenue crossing, some portions of the arroyo could not be accessed due to rough terrain. Specific rationales used to locate the soil borings are discussed below.

- According to ADEQ files (specifically the document *Phase 4 Remedial Investigation Workplan, Mission Industries,* by EMCON, November 29, 1995), surface discharges of diesel fuel had reportedly entered the Arroyo Chico in the 1960s via the Railroad Wash, which enters the arroyo just west of Kino Parkway. This section of the arroyo (extending to just west of Cherry Avenue) is currently lined with concrete along the bottom and sidewalls. However, the arroyo was previously unpaved and soils in the arroyo could have been impacted by the diesel fuel discharges. The arroyo has been incised (eroded deeper) since the time of the diesel fuel discharges, based on review of historical aerial photographs at the COT. Erosion of the base of the arroyo may have removed those soils that were potentially the most impacted.

  Initially, three borings (B-1, B-2, and B-3) were proposed for the concrete-lined portion of the Arroyo Chico, just downstream of the mouth of the Railroad Wash. During mobilization activities, it was found that these three boring locations could not be accessed by drilling vehicles due to rough terrain caused by eroded caliche beds. A series of storms dropping heavy rains also delayed potential access to this area due to running water in the arroyo. Therefore, these boring locations were not drilled, and this portion of the arroyo was later sampled by cutting through the concrete with a jackhammer and using hand sampling tools to collect near-surface soil samples from beneath the concrete. These samples are discussed later in this section under near-surface samples.

- Borings B-4, B-5, and B-6 were located progressively downstream (west) of the proposed location of boring B-3. Borings B-5 and B-6 were located just east and west of Highland Avenue, respectively. The arroyo west of the location of Boring B-6 was inaccessible to vehicles due to a concrete “berm” structure that crossed the arroyo and eroded caliche beds downstream of this structure.

- Boring B-7 was located adjacent to a property at 1041 East Miles Street. This property address was identified in the AGRA Phase I ESA report as 1130 and 1140 East 13th

Street; however, based on field evidence and discussions with the COT, it was determined that the Miles Street location was correct.

Activities associated with the property at 1041 East Miles Street have included automotive painting, body repair, and production of synthetic landscape rocks. Several 55-gallon drums of urethane foam and associated chemicals were observed on the property during the AGRA investigation, and stained soil and distressed vegetation were observed on the vacant land adjoining the facility to the east. Boring B-7 was placed just east of the facility property in a small drainage where surface drainage from the facility property would flow.

- Boring B-8 was placed south of an automotive facility located at 1028 East Broadway Boulevard. The AGRA report found that former occupants of the property had performed electric motor repair and identified stained soil on the north bank of the arroyo immediately south of the property. Runoff from the automotive property evidently flows southward to the arroyo, then enters a concrete structure that protects the side of the arroyo from erosion. Boring B-8 was drilled in a small, low-lying area north of the concrete structure. Runoff apparently pools in this low area before flowing into the arroyo.

All five borings were drilled to depths of about 15 feet below ground surface (bgs) as requested in the COT Request For Bid. Soil samples were collected from depths of about 2 and 15 feet bgs in each of the borings. These sample depths provided representation of soil conditions to the full depth of drilling, and were intended to identify significant contamination problems extending into the subsurface.

Soil Boring Activities

SCS retained Maxim to provide drilling services for the shallow soil borings. Ms. Patricia Hartshorne of SCS oversaw the drilling of the borings and collected soil samples. Maxim drilled the five accessible 15-foot soil borings (B-4, B-5, B-6, B-7, and B-8) on January 28 and 29, 1998. The borings were drilled with a CME-75 drill rig using a 5-inch diameter auger. Evidence of staining or odors in cuttings or samples was not observed during drilling of the borings. Rough terrain prevented access to proposed boring locations B-1, B-2, and B-3. A map showing the five boring locations is included on Figure 2. Site photographs are included in Appendix C. Soil boring logs are included in Appendix D.

Two drive soil samples were collected from each of the five borings at depths of about 2 and 15 feet bgs. All of the samples were analyzed for VOCs and semi-VOCs. The two samples from the boring adjacent to 1028 East Broadway Boulevard (boring B-8) were also analyzed for PCBs due to former electrical motor and equipment repair activities at the property.

DEEPER SOIL BORING

Rationale

One 40-foot soil boring was proposed for the project. The boring was located in an area where surface disposal of dry-cleaning wastes had been reported. According to ADEQ files (specifically the document *Phase 4 Remedial Investigation Workplan, Mission Industries,* by EMCON, November 29, 1995), still bottom and mop oil wastes from Haskell Linen were allegedly disposed on the vacant property east of Fremont Avenue between 13th and Manlove Streets. EMCON's review of ADEQ files found that samples were collected and analyzed from surface soil and soil piles on the vacant property, and that four soil pile samples and one surface soil sample contained tetrachloroethene (PCE) ranging from 4.7 to 200 parts per billion (ppb). The majority of the soil was reportedly removed and transported to California for disposal as hazardous waste, leaving "uncontaminated" soil on the property. An Arizona Department of Health Services (ADHS) letter to Haskell Linen in 1982 reportedly stated that the PCE cleanup had been satisfactorily completed.

Based on their review of ADHS notes, EMCON created a figure (Figure 10 in the EMCON Phase 4 workplan) showing the approximate location of samples collected from soil piles and surface soil on the vacant property. EMCON could not determine the locations where some of the samples were collected. Based on the EMCON map, SCS placed the 40-foot soil boring (B-9) in the vicinity of the one surface soil sample that had exhibited a detectable concentration of PCE. The boring was located on the vacant lot owned by the COT just south of 13th Street and east of Fremont Avenue.

Soil Boring Activities

SCS retained Maxim to provide drilling services for the deeper soil boring (B-9). Ms. Hartshorne of SCS oversaw the drilling of the boring and collected soil samples. Maxim drilled the 40-foot soil boring on January 29, 1998 with a CME-75 drill rig using an 8-inch diameter hollow stem auger. Evidence of staining or odors in drill cuttings or samples was not observed during drilling of the boring. A map showing the boring location is included on Figure 2. Site photographs are included in Appendix C. The soil boring log is included in Appendix D.

Six drive soil samples were collected from the boring at depths of about 2, 8, 15, 22, 30, and 40 feet bgs. All six samples were analyzed for VOCs and three of the samples were analyzed for semi-VOCs (B9-2, B9-15, and B9-40).

SURFACE AND NEAR SURFACE SOIL SAMPLING

Rationale – Surface Soil Samples

Surface soil samples were collected in the arroyo to supplement the information obtained from the subsurface soil borings. Three of the four surface samples were collected to evaluate the nature of dark-colored soils observed in the banks of the wash. These sample locations were between Santa Rita and Fremont Avenues (G3-S and G-4) and east of Highland Avenue

(G2-S). These bank areas were typically moist, apparently due to the retention of water above relatively impermeable caliche beds, and moss commonly covered the damp surfaces. During sampling of these soils, it was found that the dark coloration was actually a surface coating, apparently composed of dead moss.

One of the surface soil samples (G1-S) was collected from soil on the bottom of the arroyo east of Highland Avenue. The sample was collected adjacent to a narrow channel in the central portion of the arroyo that had eroded down to caliche. The soil adjoining the eroded channel likely represents a longer period of deposition than other areas of surface soil on the arroyo bottom. This location was thus judged more likely to contain residual contamination (if present).

In addition, samples collected from two of the four surface soil sample locations (G1-S and G2-S) were analyzed for the presence of tritium. During the 1970s, a release of tritium to the atmosphere reportedly occurred at American Atomics, located at Plumer Avenue and the Arroyo Chico upstream of the site. The presence or absence of residual tritium in the channel sediments of the arroyo had not previously been investigated.

Rationale – Near Surface Samples

Near surface soil samples were collected in the arroyo to supplement the information obtained from the subsurface soil borings and to collect samples in areas that were inaccessible to the drill rig. Areas of the arroyo containing caliche within two feet of the ground surface could not be sampled by the hand-driven soil probe or hand auger. All except one (S1-2) of the nine soil probe/hand auger sample locations were placed in portions of the arroyo inaccessible to vehicles. Two of these samples (S2-2 and S3-2) were collected from between Santa Rita and Fremont Avenues. Six of these samples (S4-2, S5-2, S6-2, S7-0.5, S8-1, and S9-1) were collected from the concrete-lined portion of the arroyo where three of the proposed soil borings could not be drilled due to vehicle access problems. Refusal was experienced during collection of three of the samples (S7-0.5, S8-1, and S9-1) due to the presence of subsurface rocks or caliche.

One of the near surface soil samples (S1-2) was collected from the area just east of the concrete "berm" structure west of Highland Avenue. This sample was collected from a grassy terrace of soil along the north side of the arroyo bottom. The terrace soil appeared to represent a longer period of deposition than the surface sandy soil in the central portion of the arroyo bottom. This location was therefore judged more likely to contain residual contamination (if present).

Sampling Activities

Ms. Hartshorne of SCS collected four surface soil samples from the bottom and lower sidewalls of the arroyo (G1-S, G2-S, G3-S, and G-4) using a sample scoop. Ms. Hartshorne also collected three near surface soil samples from the upper two feet of soil in the arroyo (S1-2, S2-2, and S3-2) using a hand-driven soil probe. Three of the six near surface samples located in the concrete-lined portion of the arroyo (S4-2, S5-2, and S6-2) were collected by Ms. Hartshorne and Mr. Brad Anderer of SCS using a hand-driven soil probe; the other three samples (S7-0.5, S8-1, and S9-1) were collected using a hand auger after the soil probe broke. A jackhammer was used to break through the concrete prior to the sample collection, and the concrete was patched following collection of the samples.

Evidence of staining and odors was not observed during collection of surface or near surface soil samples. A map showing the sampling locations is included on Figure 2. Site photographs are included in Appendix C.

The 13 soil samples were collected on January 28, 29, and 30, and March 17 and 18, 1998. All 13 samples were analyzed for VOCs and semi-VOCs. In addition, two of the surface samples (G1-S and G2-S) were analyzed for tritium.

SOIL SAMPLING METHODOLOGY

The soil samples collected from the 15- and 40-foot borings were collected directly into decontaminated brass sleeves inside a decontaminated split-spoon drive sampler. The surface soil samples were placed into decontaminated brass sleeves using a decontaminated sample scoop. The soil probe samples were collected directly into new plastic tubes that had been inserted into the decontaminated probe sampler. The hand auger soil samples were placed into decontaminated brass sleeves directly from the auger. The brass sleeves were sealed with sheets of Teflon covered by plastic end caps. The plastic tubes were sealed with sheets of Teflon covered by plastic end caps or taped to the end of the tube using clear packing tape.

Each sample was labeled with a unique identification code indicating the type of sample, location number, and depth of the sample. The sample was sealed within a zip-lock bag and immediately stored in an insulated cooler with ice until delivery to the analytical laboratory. The samples were transported to the analytical laboratories under chain of custody procedures.

Sampling equipment was decontaminated prior to and between collection of samples using Liquinox non-phosphate, laboratory-grade detergent in tap water, followed by two rinses of analyte-free deionized water. The drill rig boring augers were decontaminated prior to arriving on site. None of the auger flights was re-used between borings unless they were decontaminated.

LABORATORY ANALYSES

Methodology

SCS sent the soil boring samples, surface soil grab samples, and soil probe/hand auger soil samples by courier to TGI for same-day delivery on January 29 (6 samples), and January 30, 1998 (12 samples), and for next morning delivery on January 30 (5 samples), March 17 (3 samples), and March 18, 1998 (3 samples). A five-day turnaround time was specified for sample analyses as requested by the COT/County. The samples were analyzed by TGI as follows:

- 29 soil samples were analyzed for VOCs (EPA Method 8260);
- 26 soil samples were analyzed for semi-VOCs (EPA Method 8270);
- 2 soil samples were analyzed for tritium (EPA Method 906); and
- 2 soil samples were analyzed for PCBs (EPA Method 8081).

In addition, SCS sent three soil samples from the 40-foot soil boring (B9-15, B9-30, and B9-40) by courier to Maxim for overnight delivery (arrived on February 19, 1998) for analysis of geotechnical parameters (bulk density, permeability, porosity, and percent moisture). TGI analyzed the same three samples for Total Organic Carbon (TOC) in the event that this information was necessary for vadose zone contaminant transport modeling.

Laboratory Analytical Results

Below is a summary of the laboratory analytical results obtained for the shallow soil assessment samples. A summary of sample analyses and results is included in Tables 1 and 2. The laboratory analytical reports are included in Appendix E. Figure 2 shows the analytical results for those samples with detectable concentrations of analyzed compounds.

- ***VOCs:*** None of the 29 samples collected during the shallow soil assessment activities contained concentrations of VOCs above the respective laboratory method detection limits.

- ***Semi-VOCs:*** Only one of the 26 soil samples analyzed for semi-VOCs contained concentrations of these compounds above the respective laboratory method detection limits. Surface sample G1-S contained low concentrations of fluoranthene (0.460 micrograms per kilogram [µg/kg]) and pyrene (0.400 µg/kg), both of which are components of diesel fuel. Neither of these concentrations exceeds the ADEQ

Residential Soil Remediation Levels (SRLs) (effective date December 4, 1997), which are 2,600 milligrams per kilogram (mg/kg) for fluoranthene and 2,000 mg/kg for pyrene.

- ***PCBs:*** Neither of the two soil samples analyzed for PCBs contained concentrations of these compounds above the respective laboratory method detection limits.

- ***Tritium:*** The two samples analyzed for tritium (surface samples G1-S and G2-S) both contained low concentrations (0.02±0.03 picoCuries per gram [pCi/g] and -0.01±0.04 pCi/g, respectively) of this radiation. SCS contacted Mr. Gary Freeland, the laboratory manager at the Arizona Radiation Regulatory Agency for information regarding the results of this analysis. According to Mr. Freeland, the presence of tritium would not be expected in these soil samples; however, the results were very low, and obtaining a zero level of activity is essentially impossible due to ever-present background activity. Mr. Freeland also stated that the sample results were below the Minimum Detectable Activity (MDA) reported by the laboratory, which is the minimum activity level for which there is confidence in the accuracy of detection.

- ***Total organic carbon (TOC):*** TOC content was 0.27 percent in sample B9-15, 0.31 percent in B9-30, and 0.05 percent in B9-40.

- ***Physical properties:*** The three samples analyzed for physical properties (B9-15, B9-30, and B9-40) were disturbed by sample collection and/or transportation to the laboratory, so the laboratory did not perform the proposed permeability test on these samples. However, porosity, moisture content, and dry density analyses were performed. The following results were obtained:

  - **Moisture content:** 4.0 percent (B9-15), 2.3 percent (B9-30), and 4.3 percent (B9-40)

- **Dry density:** 105.6 pounds per cubic foot (lbs/cf) (B9-15), 114.3 lbs/cf (B9-30), and 110.3 lbs/cf (B9-40)

- **Porosity:** 59.0 percent (B9-15), 32.0 percent (B9-30), and 34.0 percent (B9-40).

CONTAINERIZATION AND DISPOSAL OF INVESTIGATIVE-DERIVED WASTE

Soil cuttings and decontamination wastewater produced during the drilling of the 15- and 40-foot borings were collected into 5-gallon buckets during drilling. Evidence of staining or odors in cuttings or samples was not observed during drilling of the borings. The cuttings and wastewater were placed in the roll-off bin that contained drill cuttings from monitoring well WR-345. Characterization and disposal of these materials is described in Section 6 of this report.

CONCRETE VAULT STRUCTURE

The AGRA Phase I ESA report identified a subsurface vault at the property located at 1130 and 1140 East 13th Street. However, based on field evidence and discussions with the COT, it was determined that the vault was actually located in the rear portion of the property at 1041 East Miles Street; the approximate location of the vault is shown on Figure 2. At the time of the site investigation, the property was occupied by Naturescapes Inc., a company that manufactured cast stone for landscaping. The following research was performed to determine the use of the subsurface vault and identify potential environmental concerns associated with the vault.

- SCS contacted the COT Fire Department on January 13, 1998 for information regarding the property containing the vault. According to personnel at the fire department, there was only one certificate of occupancy in the file for the address 1041 East Miles Street. SCS did not review the COT Fire Department file for the property.

- SCS reviewed COT building record files for the property on January 13, 1998. According to the building plans, the vault is a sand and grease interceptor connected to the public sewer. The plan detail for the interceptor shows the capacity as 403 gallons, and shows one inlet pipe, one outlet pipe, and two compartments.

  The files indicated that the property was developed in 1984 and the original occupant was S&J Auto Detailing (auto washing and cleaning). A business license information form in the file for S&J Auto Detailing listed an average quantity of 15 gallons of lacquer thinner used per month. The power was reconnected at the property in June 1996; the new owner (and possibly occupant) was identified as “Mexican Tele. Co.” The power was again reconnected in March 1995 for the occupancy of Naturescapes Inc.

- SCS contacted Pima County Waste Water (PCWW) on January 22, 1998 for information regarding the property containing the vault. According to personnel at PCWW, they did not have a file for this property.

SECTION 4
INITIAL STORMWATER INFILTRATION ASSESSMENT

OVERVIEW

A Stormwater Infiltration Assessment (percolation testing) was performed as specified by the COT and County under the original scope of work in order to characterize the subsurface lithologic profile and determine the potential infiltration characteristics of the subsurface materials at specific locations across the site at the proposed stormwater detention basins. Maxim was retained to perform percolation tests at six locations within the Arroyo Chico project area. Bottom elevations for the detention basins (based on one of the proposed flood control plans) were provided to Maxim by the County, and ranged from 17 to 29 feet below the existing ground surface at the test boring locations. These depths were below the caliche that occurs at an approximate depth of 15 to 20 feet bgs. Maxim's report providing details of this assessment is attached as Appendix F.

MOBILIZATION

A meeting was held at the site on January 8, 1998 and was attended by representatives from the COT, Maxim, and SCS to discuss proposed percolation test boring locations and methodology. SCS also met with Maxim at their office on January 15, 1998 to finalize the boring locations and methodology based on discussions of the project goals during the kick-off and site meetings.

Overhead and underground utilities in the boring areas were located prior to commencement of the drilling activities, as discussed in Section 3 of this report. No subsurface utilities were identified in the drilling locations planned for this investigation.

PERCOLATION TEST BORINGS

Overview

Maxim drilled six exploratory test borings (P1 through P6) and performed percolation tests from January 26 through January 30, 1998. Locations of the borings are shown on Figure 2 and in the Maxim report in Appendix F. A summary of the investigation is discussed below.

Soil Conditions

Soils encountered on the site were described as clayey sands (SC) and silty sands (SM), with variable amounts of gravel. One to 6 feet of fill soil was observed at the test boring locations. Slight to moderate calcareous cementation (caliche) was encountered in the test borings, and in all but boring P2, a 12- to 18-inch thick well-cemented zone was encountered. The depth at which this zone was encountered was about 9 or 10 feet bgs in P1, P4, and P5; about 14 feet bgs in P6; and two zones in P3 at about 19 and 22 feet bgs. No evidence of soil staining or odors in drill cuttings was observed during drilling of the borings.

Percolation Testing Methodology

In order to minimize lateral infiltration effects as much as possible, the six borings were lined with large diameter full-length PVC casings and the open space between the casing and boring wall was sealed with bentonite and filled with soil cuttings. Problems with leakage were encountered in the casing and bentonite seal of test boring P2. Horizontal infiltration was evaluated in test boring P3 by drilling two additional borings approximately 10 feet south and 10 feet west of boring P3.

Constant head and falling head type percolation tests were performed in the site test borings. Three different water levels (heads) were used to perform constant head testing within the lined test borings. Water level declines were then measured until the borings were dry or nearly dry.

Results

Percolation rates observed during falling-head tests in the test borings ranged from 4.3 feet per day to 62.0 feet per day, depending on the test location and the amount of hydraulic head (5 or 10 feet) applied to the test. The slowest percolation rates (4.3 and 9.1 feet per day under 5 and 10 feet of head, respectively) were observed in the test location closest to the Mission Linen property across the street from the site.

The measurements of water level declines in the test borings indicated that the test holes would empty/drain in less than the maximum anticipated 36-hour detention time in all borings except P3, which had the slowest infiltration rate. Rapid dewatering in boring P2 was apparently due to a leaking casing seal, and thus does not accurately represent conditions in this test boring. Visual observations of the borings drilled adjacent to P3 did not indicate that horizontal water seepage had occurred in the boring.

Maxim concluded that, based on these localized percolation test results, a significant amount of water would infiltrate into the subsurface soils underlying the detention basins following periods of significant rainfall and subsequent stormwater runoff. Maxim calculated the potential depth of saturation beneath the basins during a 36-hour holding period by using very conservative assumptions and a methodology consisting of a simple volumetric calculation. The estimated depth of saturation calculated by Maxim ranged from 48 to 61 feet bgs for a 36-hour hold time, 32 to 56 feet for a 12-hour hold time, and 13 to 45 feet for a 6-hour hold time.

However, infiltration rates over the entire basin area would likely be much less due to factors including (but not limited to) air entrainment, evapotranspiration, siltation, and compaction. In addition, this methodology assumed that nearly all the water percolated in a vertical direction; however, the methodology could not completely eliminate the effects of lateral percolation. Because the methodology did not account for the above factors, the obtained results were assumed to be very conservative. Discussion of the results of this and other assessments performed at the site and limitations and assumptions is included in Section 10.

SECTION 5
ADDITIONAL SOILS INVESTIGATION AND STORMWATER INFILTRATION ASSESSMENT

OVERVIEW

Following completion of the initial infiltration assessment by Maxim, additional meetings were held with the COT and County to discuss infiltration test results, and later with Montgomery on July 28 and October 27, 1998 to discuss the scope of work for the Additional Soils Investigation and Infiltration Assessment. The County requested that additional investigation using double-ring infiltrometer testing be performed to clarify the initial infiltration results. The primary objective was to further evaluate whether infiltration of water from the proposed stormwater detention basins would impact groundwater beneath the site. This investigation also provided additional characterization of the soil profile and the extent of caliche within the channel and proposed basin areas.

Montgomery excavated eight infiltration test pits, performed seven double-ring infiltrometer tests in readily accessible locations within the channel of the Arroyo Chico, and "small basin" percolation tests in three of the infiltration test pits within the channel. In addition, the investigation included the excavation of ten backhoe trenches within the channel and drilling of six soil borings adjacent to the channel in order to provide a detailed lithologic characterization. A copy of Montgomery's report is included in Appendix G.

FIELD ACTIVITIES

Excavation of Backhoe Trenches and Infiltration Test Pits

On November 19 and 20, 1998, ten backhoe trenches were excavated to depths of 5 to 10 feet bgs in the Arroyo Chico channel under the direction of Montgomery. The trenches were located to provide optimum coverage of the accessible portions of the channel. The channel of the Arroyo Chico is incised to a depth of 15 to 20 feet bgs; therefore, the depths of the trenches corresponded to depths of approximately 25 to 30 feet below the surface of the properties adjoining the channel. The lithologies observed in the trench soil profiles were used by Montgomery to select the general locations and depths of the infiltration test pits.

Eight test pits were excavated in the Arroyo Chico channel from November 20 to 24, 1998. Montgomery performed infiltration tests in seven of the eight test pits at depths of 3 to 5.2 feet bgs, which was at a depth interval generally equivalent to sediments lying beneath the base elevation of the proposed basins. Three infiltration test pit locations (IT-1, IT-2, and IT-3) were placed in the channel on the western portion of the site within the boundaries of the proposed stormwater detention Basin 1. Two infiltration test pit locations (IT-4 and IT-5) were placed west of Highland Avenue within the boundaries of proposed Basin 2. Two infiltration test pit locations (IT-6 and IT-8) were placed east of Highland Avenue within the boundaries of proposed Basin 3. One of the test pits located east of Highland Avenue (IT-7) was not used for infiltration testing due to the presence of moderately to well-lithified sediments at the targeted test depth.

Locations of the backhoe trenches and infiltration test pits are shown on Figure 1 in the Montgomery report. Lithologic information for the trenches and test pits is provided in Table 1, Figures 2 through 4, and Appendices A through C in the Montgomery report.

Infiltrometer and Small Basin Tests

Montgomery performed infiltrometer tests in the seven test pits on November 20 through 24, 1998 using a constant-head double-ring infiltrometer. A detailed description of the testing methodology is provided in the Montgomery report. Testing was performed by maintaining a constant head of about 6 inches of water within the inner of the two rings for less than two hours for the coarsest, most permeable sediments, to about 3.5 hours for the most cemented, least permeable sediments. The tests were generally halted when the infiltration rates stabilized.

In addition, Montgomery performed "small basin" infiltration tests in three of the seven infiltration test pits at the same depths as the double-ring infiltrometer tests in order to evaluate infiltration rates for larger areas and to verify results from the infiltrometer tests. The approximate areas evaluated by the double-ring infiltrometer tests were 0.8 square feet in size and the areas evaluated during the small basin infiltration tests ranged from about 25 to 49 square feet. Water was placed within the small basin test area to a depth of approximately 6 inches, and when the depth had dropped 2 inches, the basin was filled back up to the 6-inch depth. Although a constant head was not maintained, this method provided a semi-quantitative comparison for the double-ring infiltrometer tests.

Following completion of the double-ring and small basin infiltration tests, shallow soil samples were collected from beneath the test areas and were analyzed for particle size distribution. The test pits were then further excavated to characterize the sediments and to evaluate the wetting pattern beneath the test areas. Because the soils contained pre-existing moisture from recent rainstorms, wetting patterns from the testing were not evident in most of the test pits.

Small basin infiltration tests had been planned for well-lithified areas exposed at the base of the Arroyo Chico channel or occurring at shallow depths below the channel. Instead of using constructed basins, the changes in water depth in seven naturally occurring depressions in the well-lithified caliche in the channel were monitored for approximately one week. The depressions contained ponded water due to a stormwater flow event that occurred from November 9 to 11, 1998; no additional water was added by Montgomery. The ponded areas ranged in size from 30 to more than 500 square feet. These ponded areas are identified on Figure 1 in the Montgomery report as "surface caliche test areas." Water level changes in these naturally occurring depressions in the well-lithified areas in the channel were generally very small.

Soil Borings

On November 27 and 28, 1998, six soil borings were drilled using a hollow-stem auger drilling rig within the proposed stormwater detention Basin 1 under the direction of Montgomery. Depths of the borings ranged from 38.5 to 41.5 feet bgs. Split-spoon drive samples were generally collected from 5 and 10 feet bgs, and from approximately 12 to 30 feet bgs in the borings at about 2- to 2.5-foot intervals (it was assumed that the top 12 feet of soils will be removed during construction of the proposed basins).

The borings provided nearly continuous lithologic descriptions for soils located beneath the base of the proposed detention basin, and these soils were then compared and correlated to the lithologic information obtained from the backhoe trenches and test pits. Locations of the soil borings are shown on Figure 1 in the Montgomery report. Lithologic information obtained from the soil borings is provided in Table 1, Figures 2 through 4, and Appendices A through C in the Montgomery report.

RESULTS

Lithology

Shallow vadose zone sediments on the site predominantly consist of silty and/or clayey sand. Moderately to well-lithified intervals were identified at depths equivalent to several feet below the Arroyo Chico channel in some locations, primarily in the western portion of the site, and at the surface of the channel, particularly on the eastern portion of the site. Soils were divided into five categories on the lithologic logs (Figures 2 through 4 in the Montgomery report) based on lithology (grain size distribution and degree of lithification) and on the estimated infiltration capacity. Lithologic information for the trenches, test pits, and soil borings is provided in Table 1, Figures 2 through 4, and Appendices A through C in the Montgomery report.

Infiltration Test Results

Infiltration rates measured during the double-ring infiltrometer tests initially decreased rapidly, then gradually decreased as the wetting front deepened, eventually stabilizing. The stabilized late-stage data was "fitted" with a horizontal line, which represented the steady-state infiltration capacity of the targeted test zone. The measured infiltration rates for the test pits and the type of soil at the test depths are shown on Figures 5 through 10 in the Montgomery report.

Stabilized infiltration rates for the infiltrometer tests ranged from 1.4 to 2 feet per day in IT-1, IT-2, and IT-4, and from 17 to 39 feet per day in IT-3, IT-5, IT-6, and IT-8. The low infiltration rates measured in IT-1, IT-2, and IT-4 were interpreted by Montgomery to be due to weak to moderate lithification of the sediments. The small basin tests performed at IT-1 and IT-4 also obtained low infiltration rates of 3 and 4 feet per day, respectively. Both the infiltrometer and small basin tests at IT-4 showed significant lateral migration, with a saturated depth in soils beneath the test area of only 3 to 4 inches following the testing.

The higher measured infiltration rates at infiltration test locations IT-3, IT-5, IT-6, and IT-8 were attributed to the generally non-lithified coarser grained sediments identified at those locations, and possible fracturing of weakly- to moderately-lithified sediment layers during installation of the infiltrometers. The small basin test performed at IT-6 had a measured steady state infiltration rate of 5 feet per day, approximately one-fourth the rate measured by the infiltrometer test (20 feet per day). The lower infiltration rate was considered to be more representative of the thin layer of weakly- to moderately-lithified sediments located at the test depth.

Infiltration rates measured at the naturally occurring depressions in the lithified caliche in the channel ranged from 0.04 to 0.4 feet per day. Most of the locations had infiltration rates of less than 0.1 foot per day, and those with the higher rates were found to have sediments that were only moderately lithified. These results indicated that relatively continuous and moderately- to well-lithified sediment layers could substantially limit vertical infiltration where these sediments are encountered.

APPLICATION OF RESULTS TO SITE BASINS

In order to evaluate whether infiltration of stormwater beneath the proposed stormwater detention basins would impact groundwater, Montgomery used the results of the lithologic characterization and infiltration tests to estimate a "representative average" infiltration capacity for the basins, which was used with estimated "fillable porosity" to project the potential depth of wetting front movement below the basins during a 36-hour period of stormwater detention.

Montgomery assumed that the depths of the proposed basins would be at a similar elevation as that of the base of the channel, thus preserving the moderately- to well-lithified sediments. Assuming there are discontinuities in these sediments, the overall rate of infiltration would be some average between the smallest and largest rates observed in the field. Montgomery estimated that the representative average infiltration capacity for the Arroyo Chico site would be between 3 to 10 feet per day (Silty and Clayey Sand category on Figures 2 through 4 in the Montgomery report), based on correlations of infiltration test results and lithology, and experience from other sites. Because moderately- to well-lithified sediments do not appear to be continuous in the proposed area of Basin 1, the average infiltration capacities in parts of this basin may exceed 10 feet per day. Likewise, because moderately- to well-lithified sediments may be relatively continuous in proposed Basins 2 and 3, the average infiltration capacities in parts of these basins may be less than or equal to 3 feet per day.

Montgomery used the Green-Ampt theory to apply the infiltration investigation results for the double-ring infiltrometer and small basin tests to the much larger and deeper proposed basins. This theory assumes that an infiltration wetting front moves downward as piston flow with a uniform hydraulic conductivity in the wetted zone and constant pressure head at the wetting front. Further discussion of this theory, the equation used for estimating and comparing infiltration rates, and application of this equation for the site can be found in the Montgomery report. The appropriate multiplier for converting the average infiltration rates obtained from the infiltration tests to the predicted infiltration rates for the larger scale basins was effectively cancelled out by the estimated decrease in depth of wetting due to lateral flow. Therefore, Montgomery estimated that the average infiltration rate of 3 to 10 feet per day could be applied directly to the proposed basins.

In addition, the fillable porosity (the difference between the total porosity of the soil divided by the existing volumetric water content) was estimated to be about 20 percent based on typical porosities and water contents of soils under similar conditions. Using the estimated range of representative average infiltration capacity for the proposed basins (3 to 10 feet per day) divided by the fillable porosity (20 percent), the projected depth of wetting front movement would be 15 to 50 feet per day, or 22 to 75 feet for the maximum 36-hour detention time for the stormwater.

Based on these estimates, Montgomery stated that unless a low-permeability layer was placed at the bottoms of the basins, either by natural settling out of fine sediments and organic materials from stormwater or by installation of an engineered liner, stormwater infiltrating the basins would eventually reach groundwater.

Montgomery stated that the approach used for this infiltration assessment was limited in that a more accurate evaluation would require a large amount of additional soil physical data, groundwater data, and the use of computer modeling. Various limitations identified by Montgomery for the use of the data obtained during this infiltration assessment included the following:

- The scale of the infiltration tests was very small in comparison with that of the proposed basins (constant head of 0.5 feet of water versus a variable head of up to more than 20 feet of water) and there was a very wide range of results for the infiltration rates obtained during the testing (nearly 0 feet per day up to 40 feet per day), which made development of a reasonable average infiltration rate or even a range of rates difficult.

- Lateral flow was observed in some of the double-ring infiltrometer and small basin tests; this would result in an overestimate of the steady-state infiltration rate.

- Estimates for infiltration and wetting front movement were made based on the maximum predicted depth of water of more than 20 feet for a detention time of 36 hours. Most storms would result in much smaller volumes of water stored over shorter periods of time. In addition, these estimates were prepared for a single basin-filling event. Repeated basin-filling events would result in infiltration volumes that are essentially additive, and the fillable porosity would be reduced, so that a nearly steady-state wetting pattern could develop between the land surface and groundwater.

- Moderately- to well-lithified sediments (caliche) can greatly decrease infiltration rates. The actual continuity of these lithified sediments throughout the proposed basin areas is not known. If excavation of the basins results in removal of these lithified layers, infiltration in those areas could be increased.

- Fine-grained sediments and organic materials are likely to settle out of stormwater and accumulate on the basin floor after several filling cycles. Infiltration capacity could be greatly reduced due to the accumulation of this surface "skin."

- Quantification of changes in groundwater level and hydraulic gradients due to infiltration of stormwater would require hydrogeologic characterization of the underlying aquifer system, and development and use of a groundwater flow model.

Additional discussion of the results of the infiltration assessments performed at the site and the limitations and assumptions is included in Section 10.

SECTION 6
INITIAL GROUNDWATER ASSESSMENT

OVERVIEW

The Groundwater Assessment consisted of the installation, development, and sampling of two pairs of nested groundwater monitoring wells on the site. In addition, a survey of the site wells was performed and water level measurements were collected at the site and Mission Linen wells.

BACKGROUND INFORMATION – PARK-EUCLID WQARF SITE

The project site is located partially within the Park-Euclid WQARF site (formerly called Mission Linen). SCS reviewed files and reports for the Park-Euclid WQARF site at ADEQ in January 1998. The following discussion is based on information contained in the ADEQ files at that time, as well as information contained on the ADEQ website in January 2002. Information discussed from the ADEQ file is primarily based on the EMCON document *Phase 4 Remedial Investigation Workplan, Mission Industries*, dated November 29, 1995. ADEQ figures dated May 2000 and August 2001 showing the estimated boundaries of the groundwater contamination plumes are included in Attachment 3 of SCS Technical Memorandum 1, which is included in Appendix N.

The Park-Euclid WQARF site contains two groundwater contamination plumes, one in the regional aquifer, and one in the perched aquifer. The identified boundaries of the plumes are located between Euclid and Santa Rita Avenues, and Broadway Boulevard and 14th Street. Two facilities included within this area, located at 299 and 301 South Park Avenue, were occupied by dry-cleaning operations from the late 1930s through the mid-1970s and 1980s. Mission Uniform & Linen Service (Mission Linen), a linen supply and industrial laundry facility, is currently located at 301 South Park, adjoining the subject site to the west. Investigations of the Park-Euclid WQARF site have included collection of soil and groundwater samples, soil gas surveys, installation of groundwater monitoring wells in the regional and perched aquifers, geophysical logging and abandonment of two production wells, and installation of a soil vapor extraction system.

Contamination was first identified when ADEQ collected a sample of bright green liquid from a production well at the Mission Linen facility in 1990 during investigation of diesel contamination in the area. Analysis of the sample indicated groundwater at the facility was contaminated by a combination of diesel fuel and VOCs, including PCE, trichloroethene (TCE), 1,1-dichloroethene (DCE), 1,1,2-trichloroethane (TCA), dichloromethane, trans-1-2-DCE, benzene, and xylene.

Subsequent samples from the two water production wells at Mission Linen were found to contain PCE (a chemical typically used for dry cleaning), PCE degradation products, diesel fuel, and diesel fuel components. Investigations by Earth Technology Corporation in 1991 and EMCON in 1992 measured more than 13 feet of floating diesel fuel in one of the production wells. Both water production wells were later abandoned. Monitoring wells placed on the property were found to have detectable concentrations of PCE, diesel fuel components, or both.

According to the 1995 EMCON Phase 4 Workplan, depths to groundwater in the perched aquifer wells averaged about 90 feet bgs. The perched aquifer was underlain by a clay/silt aquitard, which retards or inhibits the downward movement of groundwater. EMCON stated that the flow direction of groundwater in the perched aquifer at the Mission Linen property was generally to the north, with variations to the north-northeast and north-northwest.

The 1995 EMCON Phase 4 Workplan stated that depths to groundwater in the regional aquifer averaged 188 feet bgs. The regional aquifer was found to be under confined conditions due to well-cemented soils above the aquifer. Although groundwater in the regional aquifer generally flows to the northwest in the Tucson area, the groundwater flow direction at the Mission Linen property was found to be to the north-northeast, possibly due to groundwater pumping at the University of Arizona (UA) well field approximately one mile northeast of the property.

In September 1998, the United States Environmental Protection Agency (EPA) installed two groundwater monitoring wells in the perched aquifer upgradient of the Park-Euclid WQARF site. In October 1999, remedial investigations were initiated by ADEQ. Investigations have included installation of three groundwater monitoring wells south of the UA and downgradient of the WQARF site, installation of 12 additional groundwater monitoring wells, and sampling and analysis of groundwater from area monitoring wells and water supply wells at the UA. Samples collected from one of the recently installed downgradient groundwater monitoring wells identified contamination by PCE. No contamination has been detected in the samples collected from the UA water supply wells. ADEQ is continuing to sample the monitoring wells and water supply wells on a monthly basis. EPA informally delegated responsibility for the WQARF site to ADEQ in February 2000.

RATIONALE

Investigation of groundwater beneath the Arroyo Chico project site was requested by the COT and County in the Request For Bid for the following reasons:

- The project site was located across the street from the Mission Linen property;

- The extent and degree of contamination attributable to the Park-Euclid WQARF site had not been defined;

- The Arroyo Chico project site was potentially hydrogeologically downgradient from the Park-Euclid WQARF site, and potential contaminants associated with the WQARF site had potentially impacted groundwater beneath the project site.

Two pairs of nested groundwater monitoring wells were installed on COT properties downgradient from the Mission Linen facility property in areas outside of the proposed stormwater detention basin locations. The purpose of the groundwater assessment was to obtain groundwater depth, flow direction, and water quality information for the perched and regional aquifers in order to evaluate potential impacts by regulated compounds associated with the nearby Park-Euclid WQARF site.

MOBILIZATION

Overhead and underground utilities in the well boring areas were located prior to commencement of the drilling activities, as discussed in Section 2 of this report. No subsurface utilities were identified in the drilling locations planned for this investigation.

A permit from Arizona Department of Water Resources (ADWR) is required before drilling a groundwater monitoring well. The ADWR Notice of Intent (NOI) to drill permit applications were prepared by the COT and were then forwarded to SCS for hand delivery and payment of fees to ADWR. The drill cards were completed by ADWR the day before drilling was scheduled to begin. Copies of the ADWR drilling permits are included in Appendix H.

WELL DRILLING, INSTALLATION, AND DEVELOPMENT

Well Drilling and Construction

SCS retained Layne to provide drilling and construction services for the groundwater monitoring wells. The well borings were drilled using an AP-1000 percussion hammer drill rig. Ms. Hartshorne, Mr. Christopher Robertson, and Mr. Bradley Johnston of SCS oversaw the drilling and construction of the wells and collected soil samples. CTI delivered a 20-cubic yard roll-off container to each of the two drilling locations for the collection of drill cuttings and water. Drilling was performed only between 8:00 AM and 5:00 PM to reduce disturbance to the residential neighborhood.

Well boring MW-1 was located at the northeast corner of 13th Street and Fremont Avenue; the official COT designation for this well location is WR-347. Well boring MW-2 was located at the southwest corner of 12th Street and Santa Rita Avenue; the official COT designation for this well location is WR-345. The COT well location designations WR-347 and WR-345 are used throughout this report; however, soil and groundwater samples collected from the well borings during the initial groundwater assessment used the "MW" designations. The perched aquifer and regional aquifer wells in each nested well are indicated by adding an "A" to the well name for the perched aquifer well and a "B" for the regional aquifer well (e.g., WR-345A and WR-345B, respectively). A map showing the well boring locations is included on Figure 2. Site photographs are included in Appendix C. Well boring logs are included in Appendix I.

The boring for the WR-345 nested wells was drilled by Layne from January 26 to 28, 1998. The boring was drilled to a total depth of 238 feet bgs. The wells were constructed by Layne on January 29 and 30, 1998. The regional aquifer well (WR-345B) was screened between the depths of 180 feet and 235 feet bgs, and the perched aquifer well (WR-345A) was screened between the depths of 69 feet and 99 feet bgs. Layne set the surface completion vault at the well location on February 4, 1998 and the barricades on February 6, 1998.

Layne drilled the boring for the WR-347 nested wells from January 30 to February 4, 1998. The boring was drilled to a total depth of 238 feet bgs. Layne constructed the wells on February 5 and 6, 1998. The regional aquifer well (WR-347B) was screened between the depths of 180 feet and 235 feet bgs, and the perched aquifer well (WR-347A) was screened between the depths of 79.5 feet and 109.5 feet bgs. Layne set the surface completion vault and barricades at the well location on February 6, 1998.

The site wells were constructed using stainless steel screen (0.020-inch slots) and either low-carbon steel blank casing (regional aquifer wells) or mild steel blank casing (perched aquifer wells). Two-inch diameter casing and screen were used for the perched aquifer wells and

4-inch diameter casing and screen were used for the regional aquifer wells. The filter pack consisted of Colorado Silica Sand (8-12) and well seals consisted of coarse grade (3/8-inch) bentonite pellet Holeplug, one-quarter inch bentonite pellets, and cement grout. A locked metal vault was placed over the wells on a concrete pad and barricade posts were placed around the vault. Well construction schematics are shown on the well boring logs in Appendix I.

Observations

The soils observed in the WR-345 boring consisted of silty sand and sand with varying amounts of gravel and cobbles from ground surface to about 87 feet bgs. There appeared to be a few minor well-cemented zones (calcareous cementation) and possible interbeds of clay at some depths. Moist zones were observed from about 44 to 65 feet bgs and 75 to 80 feet bgs. Moist sandy clay and clay, corresponding to the perched aquifer and aquitard, were observed from about 88 to 104 feet bgs. Clay in the lower portion of this zone appeared to be cemented. The lithology below the aquitard consisted of sand to a depth of about 162 feet bgs. Sandy clay, clayey sand, silty sand, and sand were observed from about 162 to 238 feet bgs. Well-cemented soils were observed below about 170 feet bgs.

The soils observed in the upper portion of the WR-347 boring also consisted of silty sand and sand with varying amounts of gravel and cobbles, well cemented zones, and apparent thin clay interbeds from ground surface to about 100 feet bgs. Odors were observed in soil cuttings from about 90 to 100 feet bgs. Dense clay and sandy clay were present from about 100 to 126 feet bgs; this lithology apparently forms the clay aquitard at the base of the perched aquifer. Below the aquitard was an abrupt change in lithology to sand and silty sand, with varying amounts of clay, gravel, and cobbles. Below about 150 feet bgs, the soils were very well cemented.

Soil Sample Collection

Drive soil samples were collected at depths of 70, 90, and 100 feet bgs in WR-345 and at depths of 80, 90, 100, 110, and 150 feet bgs in WR-347. The samples were collected directly into decontaminated brass sleeves inside a decontaminated split-spoon drive sampler. The brass sleeves were sealed with sheets of Teflon covered by plastic end caps.

Each sample was labeled with a unique identification code, indicating the well location number and depth of the sample. Samples collected for environmental analyses (all except MW1-150) were sealed within zip-lock type plastic bags and immediately stored in an insulated cooler with ice until delivery to the analytical laboratory. Additional samples collected for geotechnical analyses did not need to be kept cold (MW1-100, MW1-150, and MW2-90). The samples were transported to the analytical laboratories under chain of custody procedures.

Sampling equipment was decontaminated prior to collection of samples using Liquinox non-phosphate, laboratory-grade detergent in tap water, followed by two rinses of analyte-free deionized water. The drill casing was decontaminated prior to drilling activities and between borings.

Well Development

Layne developed the groundwater monitoring wells on February 6, 1998. Static water levels obtained prior to development in the perched aquifer wells were 96.10 feet bgs in WR-347A and 95.55 feet bgs in WR-345A. Static water levels in the regional aquifer wells were 202.20 feet bgs in WR-347B and 197.35 feet bgs in WR-345B. The water level measurements are shown on Table 3.

Development water was discharged into the roll-off containers at the well sites, except for the perched aquifer water at WR-347A, which was placed into a 55-gallon drum due to apparent contamination. The wells were surged and bailed prior to pumping. Both perched aquifer wells were pumped using a 2-inch pump at about one-half gallon per minute (gpm), but were pumped dry within a couple minutes. Odor was observed in the water from the perched aquifer at WR-347A. The regional aquifer well at WR-345B was pumped using a 2-inch pump for about 97 minutes at increasing rates from 1.5 to 3 gpm. The regional well at WR-347B was pumped using a 4-inch pump at about 5 gpm for about 45 minutes. Pumping was performed until the water was running relatively clear.

COLLECTION OF GROUNDWATER SAMPLES

Groundwater samples were collected from the nested wells on February 23, 1998. GSI was retained by SCS to purge the wells prior to collection of samples. Static water levels were measured prior to purging the wells. Depths to groundwater in the perched aquifer wells were 96.48 feet bgs in WR-347A and 95.37 feet bgs in WR-345A. Depths to groundwater in the regional aquifer wells were 202.00 feet bgs in WR-347B and 197.01 feet bgs in WR-345B. The results are shown on Table 3.

The wells were purged by GSI using a 2-inch bailer (perched aquifer wells) or 4-inch bailer (regional aquifer wells) raised and lowered using a drill rig. SCS monitored field parameters (pH, conductivity, and temperature) during purging to confirm stabilization of the parameters. Bailing was stopped when three casing volumes had been removed from the well or stabilization of field parameters had been achieved.

Purge water from each regional aquifer well was placed into two 55-gallon drums located at each well site. Purge water from the perched aquifer wells was placed into the same 55-gallon drum containing development water for perched aquifer well WR-347A, located at the WR-347 well site. Drums were labeled to reflect their respective contents.

Samples were collected by Ms. Hartshorne of SCS using new disposable bailers at each well. Two preserved volatile organic analyte (VOA) vials and two 1-liter amber bottles were filled at each well for VOC and semi-VOC analyses, respectively. A duplicate sample was collected from perched aquifer well WR-347A for the semi-VOC analysis and from regional aquifer well WR-347B for the VOC analysis. Water sampling logs are included in Appendix J.

LABORATORY ANALYSIS

Methodology – Soil Samples

SCS delivered three drive soil samples from the WR-345 boring to TGI on January 29, 1998. SCS sent four drive soil samples from the WR-347 boring by courier to TGI for same-day delivery on February 4, 1998. A 5-day turnaround time was specified for sample analyses by request of the COT. Seven soil samples were analyzed for VOCs (EPA Method 8260) and semi-VOCs (EPA Method 8270).

In addition, SCS sent one soil sample from the WR-347 boring by courier to Maxim for overnight delivery (arrived on February 19, 1998) for analysis of geotechnical parameters (bulk density, permeability, porosity, and percent moisture). One additional soil sample from WR-347 and one soil sample from WR-345 were delivered to Maxim on February 26, 1998 for the same analyses. TGI analyzed two samples (MW1-100 and MW2-90) for TOC in the event this information was needed for vadose zone contaminant transport modeling.

Methodology – Groundwater Samples

SCS delivered four groundwater samples (MW-1A, MW-1B, MW-2A, and MW-2B) and one duplicate for each of the two analyses to Turner Laboratories on February 24, 1998. A five-day turnaround time was specified for sample analyses by request of the COT. The four groundwater samples were analyzed for VOCs (EPA Method 624) and semi-VOCs (EPA Method 625). One duplicate analysis for VOCs was performed for sample MW-1B. One duplicate analysis for semi-VOCs was performed for sample MW-1A.

Laboratory Analytical Results

Below is a summary of the laboratory analytical results obtained for the samples collected from the two site well locations. A summary of sample analyses and results is included in Tables 1 and 2. The laboratory reports are included in Appendix K.

- ***Soil Samples:*** Four soil samples were collected and analyzed from well boring location WR-347 and three soil samples were collected and analyzed from well boring location WR-345. None of the seven soil samples collected during the drilling of the two well locations contained concentrations of VOCs or semi-VOCs above the respective method detection limits. The three samples analyzed for physical properties (MW1-100, MW1-150, and MW2-90) were analyzed for permeability, porosity, moisture content, dry density, and TOC (no TOC analysis was performed for MW1-150). The results for these analyses are listed below:

    - **Permeability:** 6.9×10^{-7} centimeters per second (cm/sec) (MW1-100), 2.1×10^{-6} cm/sec (MW1-150), and 6.0×10^{-6} cm/sec (MW2-90)

    - **Porosity:** 33.0 percent (MW1-100), 27.0 percent (MW1-150), and 47.0 percent (MW2-90)

    - **Moisture Content:** 13.7 percent (MW1-100), 8.7 percent (MW1-150), and 30.6 percent (MW2-90)

    - **Dry Density:** 113.4 lb/cf (MW1-100), 122.6 lb/cf (MW1-150), and 89.7 lb/cf (MW2-90)

    - **TOC:** 0.25 percent (MW1-100) and 0.10 percent (MW2-90)

- ***Groundwater Samples:*** Groundwater samples MW-1A, MW-1B, MW-2A, MW-2B and duplicate samples were collected and analyzed. Groundwater sample MW-1A from perched aquifer well WR-347A contained detectable concentrations of PCE (34 micrograms per liter [µg/L]). The duplicate analysis for this sample detected a concentration of 5 µg/L of naphthalene. Groundwater sample MW-2B from regional aquifer well WR-345B contained a detectable concentration of PCE (2.9 µg/L). The Aquifer Water Quality Standard (AWQS) for PCE is 5 µg/L. No AWQS for naphthalene has been established.

  In addition, all four groundwater samples and the duplicate analysis (for sample MW-1A) contained detectable concentrations of bis (2-ethylhexyl) phthalate ranging from 14 µg/L in sample MW-1B to 130 µg/L in MW-2B. No AWQS for bis (2-ethylhexyl) phthalate has been established. Phthalates are typically related to plastic compounds, and it is assumed that their presence in these samples may have been associated with drilling or sampling procedures.

CONTAINERIZATION AND DISPOSAL OF INVESTIGATIVE-DERIVED WASTES

Containerization

One 20-cubic yard roll-off container was placed by CTI next to each of the two groundwater well locations to collect cuttings and wastewater generated during drilling and development activities. A 55-gallon drum was also placed next to well location WR-347 by Layne to separately collect development water from the perched aquifer, since it was anticipated that this location was likely to encounter contamination in the perched aquifer. Purge water generated during sampling of both perched aquifer wells was also placed in this drum. Additional drums were placed at each well site by GSI for collection of purge water from the regional aquifer wells. Drums were labeled to reflect their contents.

Sample Collection and Analysis

SCS collected a total of five investigative-derived waste (IDW) samples from the two roll-off containers and one 55-gallon drum that contained soil and wastewater generated during drilling, construction, and development of the two site groundwater monitoring wells. Three wastewater samples were collected on January 30, February 6, and February 10, 1998: one from each roll-off container and one from the 55-gallon drum. Two composite soil samples were collected: one from the roll-off container located next to WR-345 on February 2, 1998 and one from the roll-off container located next to WR-347 on February 11, 1998.

SCS delivered one wastewater sample to ATEL on January 31, 1998 and two wastewater samples to Turner on February 9 and 10, 1998. SCS sent the soil samples by courier to TGI for same-day delivery on February 2 and 11, 1998. A 5-day turnaround time was requested for sample analyses in order to meet project schedules. The following analyses were performed:

- 3 wastewater samples were analyzed for VOCs (EPA Method 624); and

- 2 soil samples were analyzed for total petroleum hydrocarbons (TPH: ADHS 418.1AZ), VOCs (EPA Method 8260), and semi-VOCs (EPA Method 8270).

In addition, the analytical results from the four groundwater samples and sample duplicates collected from the site wells on February 23, 1998 were used to characterize the purge water contained in the additional 55-gallon drums.

Laboratory Analytical Results

Below is a summary of the laboratory analytical results obtained for the IDW samples. A summary of sample analyses and results is included in Tables 1 and 2. The laboratory reports are included in Appendix K.

- Both soil samples from the two roll-off containers had low concentrations of TPH (29 mg/kg and 64 mg/kg). Sample MW1-IDW from the roll-off container at well location WR-347 also had a low concentration (1,200 μg/kg) of the plastic compound bis (2-ethylhexyl) phthalate.

- Wastewater samples MW1-IDW and MW2-IDW collected from the two roll-off containers did not contain detectable concentrations of VOCs.

- Wastewater sample MW1-IDW2 from the 55-gallon drum containing development water from perched aquifer well WR-347A contained a low concentration of PCE (3.6 μg/L).

- Groundwater sample MW-1A and the duplicate sample from perched aquifer well WR-347A contained PCE at a concentration of 34 μg/L and naphthalene at 5 μg/L. Groundwater sample MW-1B from regional aquifer well WR-347B did not contain detectable VOCs. Groundwater sample MW-2A from perched aquifer well WR-345A did not contain detectable VOCs, but a low concentration of PCE (2.9 μg/L) was detected in regional aquifer sample MW-2B. In addition, groundwater samples from all four wells contained bis (2-ethylhexyl) phthalate at concentrations ranging from 14 to 130 μg/L.

Disposal

CTI pumped wastewater from both roll-off containers on February 10, 1998 using a pump truck; the containers were pumped in separate trips and were stored at the CTI property in a tank and drums. Roll-off containers were pumped a second time a couple weeks later to remove the remaining liquid that had settled out in the containers after the first pumping. The roll-off containers were removed from the site on March 20, 1998, and the soil was disposed of at USA Waste's Sierra Estrella Landfill in Maricopa, Arizona on March 24, 1998. Bulk wastewater removed from the roll-off containers was transported to CTI's Phoenix facility and was later disposed at the DeMenno/Kerdoon facility in Compton, California on April 7, 1998. Drums of development and purge water were disposed of at the Butterfield Station Regional Landfill in Mobile, Arizona on June 3, 1998 and at the Laidlaw Environmental Services facility in Phoenix, Arizona on June 15, 1998. Copies of bills of lading and disposal receipts are included in Appendix K along with the laboratory results for analysis of IDW samples.

DEPTH TO GROUNDWATER MEASUREMENTS

Depths to groundwater were measured in the site wells during drilling and construction of the wells and following completion of the wells to obtain estimates of the static water levels in the perched and regional aquifers. Static water levels in the wells were measured on February 6, 1998 prior to well development and on February 23, 1998 prior to purging of the wells for groundwater sampling. Groundwater levels in the perched aquifer wells ranged from 96.10 to 96.48 feet bgs in WR-347A and from 95.29 to 95.55 feet bgs in WR-345A. Depths to groundwater in the regional aquifer wells ranged from 200.00 to 202.20 feet bgs in WR-347B and 197.01 to 197.35 feet bgs in WR-345B. Results of water level measurements are shown in Table 3.

SCS contacted the attorney for Mission Linen on February 18, 1998 to arrange access to the groundwater monitoring wells located on the Mission Linen property. Dames & Moore, the consultant for Mission Linen, contacted SCS on February 19, 1998 to schedule access to the Mission Linen wells. Because removal of the cover plates to the regional aquifer wells at Mission Linen required a special 5-sided socket wrench, Dames & Moore was not able to provide access to those wells until a suitable wrench was obtained. Measurements of the regional aquifer wells were thus collected at a later date.

Ms. Hartshorne of SCS met with Mr. Brian Anderson of Dames & Moore at Mission Linen on February 25, 1998 to measure depths to groundwater in the perched aquifer wells (MLS-4, MLS-5, and MLS-6) and on March 20, 1998 to measure depths to groundwater in the regional aquifer wells (MLR-1, MLR-2, MLR-3, and MLR-7). Depths to groundwater in the subject site perched aquifer wells and regional aquifer wells were measured at the same time as the corresponding Mission Linen wells in order to obtain comparable data. A Solinst Model 122 300-foot Oil/Water Interface Meter was used by SCS for groundwater depth measurements.

Depth to groundwater measured in the site perched aquifer wells was 96.51 feet bgs in WR-347A and 95.29 feet bgs in WR-345A. Depths to groundwater in the Mission Linen perched aquifer wells were 89.41 feet bgs (MLS-5), 94.38 (MLS-6), and 94.60 (MLS-4). The depths to groundwater measured in the site regional aquifer wells were 201.84 feet bgs in WR-347B and 196.66 feet bgs in WR-345B. Depths to groundwater in the Mission Linen perched aquifer wells ranged from 195.25 feet to 200.52 feet bgs. Groundwater level measurements are summarized on Table 3.

Floating product (0.39 foot thick and less than 0.01 foot thick) was detected in two Mission Linen wells (MLS-4 and MLS-6), and odors were also detected one Mission Linen well (MLS-5) and one of the site wells (WR-347A). All of these wells were in the perched aquifer.

MONITORING WELL SURVEY

The Arroyo Chico site wells were surveyed by Rick Engineering on March 5, 1998 to establish the datum elevations for the depth to groundwater measurements. The elevations of the top of the well casings and the top of the concrete well pads were surveyed, as well as the latitude, longitude, and State plane coordinate. The survey referenced a benchmark specified by the COT, consisting of a T-shaped chisel mark located on the curb at the southeast corner of 13th Street and Park Avenue, elevation 2411.52 feet above mean sea level (msl). According to EMCON, this benchmark had previously been used for the survey of the wells at the Mission Linen property.

Based upon referencing of Mission Linen files, Dames & Moore provided datum elevations for the Mission Linen wells to SCS. However, there appeared to be discrepancies between the elevations for several of the wells. Based on these apparent discrepancies, the COT and County requested that another survey be performed that encompassed both the four site wells and the seven wells located on the Mission Linen property.

On March 31, 1998, COT survey personnel performed a survey of the Arroyo Chico site wells and Mission Linen wells. The datum elevations were established at the top of the north sides of the casings for the site wells and the three perched aquifer wells at Mission Linen (MLS-4, MLS-5, and MLS-6), and at the top of the north side of the sounding tubes of the four regional aquifer wells at Mission Linen (MLR-1, MLR-2, MLR-3, and MLR-7).

Rick Engineering and COT survey crews determined that the COT survey elevations were correct. The COT survey datum elevations for the Arroyo Chico site wells and Mission Linen wells are provided in Table 3. The revised Rick Engineering well site location map is provided in Appendix L. It should be noted that the elevations on the Rick Engineering map vary slightly from the COT elevations that are tabulated below. These COT elevations were used to calculate the groundwater elevations shown on Figure 3. COT elevations for the wells, measured at the north sides of the tops of casing or sounding tubes, are as follows:

- MLR-1: 2415.097 feet
- MLR-2: 2414.052 feet
- MLR-3: 2416.094 feet
- MLR-7: 2419.338 feet
- MLS-4: 2416.422 feet
- MLS-5: 2411.685 feet
- MLS-6: 2415.951 feet
- WR-347A (MW-1A): 2417.073 feet
- WR-347B (MW-1B): 2417.078 feet
- WR-345A (MW-2A): 2409.898 feet
- WR-345B (MW-2B): 2409.813 feet

GROUNDWATER FLOW DIRECTION AND GRADIENT

SCS prepared groundwater flow maps for the perched and regional aquifers, as shown in Figures 3A and 3B. Based on water level measurements collected during this assessment, groundwater in both the perched and regional aquifers flows to the northeast. Gradient varies across the site, but averages approximately 0.006 feet per foot.

SECTION 7
RISK ASSESSMENT

INTRODUCTION

A health-risk assessment was proposed as part of this investigation to evaluate potential human health risks that may be associated with potential soil or groundwater contamination beneath the Arroyo Chico site. The scope of the risk assessment was dependent on the findings of the soil and groundwater investigations that are described earlier in this report, and summarized in the following paragraph.

Soil sampling performed at locations of concern on the Arroyo Chico site did not identify the presence of soil contamination that would warrant a risk assessment for soil contamination. Sampling of two pairs of groundwater monitoring wells that were installed on the Arroyo Chico site identified the presence of groundwater contamination in both the perched and regional aquifers. It is assumed that this contamination is associated with the Park-Euclid WQARF site.

Because no soil contamination was identified on the Arroyo Chico site, evaluation of risks associated with soil contamination was not performed. However, groundwater contamination was identified. For human health risks to exist in this case, one or more exposure pathways must be present by which toxic compounds associated with the contaminated groundwater can be brought to the surface so that humans can absorb, ingest, or inhale such contamination.

Although groundwater contamination was detected beneath the Arroyo Chico site, there are no drinking water wells or other potential exposure pathways on the site, so such contamination would not present health risks to persons on the Arroyo Chico site. However, if this groundwater contamination were to continue to migrate from the Arroyo Chico monitoring well locations to an off-site drinking water well, an exposure pathway could be completed, and health risks could exist.

Therefore, a preliminary screening-level groundwater modeling assessment using an EPA-approved modeling program was performed to evaluate whether groundwater contamination in the perched aquifer could migrate from the Arroyo Chico monitoring well locations to the nearest downgradient groundwater production wells. Five such wells located in the vicinity of the UA campus were identified, approximately one-half to three-quarters of a mile north and northeast of the Arroyo Chico site.

PRELIMINARY GROUNDWATER MODELING STUDY

Overview

The objective of this preliminary groundwater modeling study was to assess the likelihood that existing PCE contamination in groundwater beneath the Arroyo Chico site and the Park-Euclid WQARF site could migrate off-site and impact the potable water wells near the UA north and northeast of the site.

The preliminary fate and transport modeling conducted for this assessment was performed in a highly conservative manner and was intended to represent worst-case conditions. It was considered to be a screening-level assessment, with a goal of determining the need and scope of future, more refined groundwater modeling efforts.

Summary of the Groundwater Model

Groundwater fate and transport modeling is a technique whereby computer simulations are used to predict the behavior of chemicals in the saturated zone. Properties of the water-bearing unit (aquifer), chemicals of concern, and source(s) of contamination are input into a computer model that attempts to mimic the environmental processes that occur in an aquifer. The output from a groundwater modeling study includes a prediction of the extent of migration and magnitude of downgradient contamination resulting from the source being modeled.

Results of groundwater modeling are significantly influenced by input data regarding aquifer properties, contaminant properties, and source properties. These input data can be based on actual site-specific data, or conservative default values and assumptions can be used. Site-specific input data will provide the most accurate predictions of groundwater and contaminant behavior. However, this assessment was based almost entirely on conservative default values and assumptions regarding these properties, so this assessment is to be considered a simplified "screening-level" modeling assessment. Such screening-level assessments provide a more qualitative evaluation of groundwater and contaminant behavior.

For this project, existing groundwater contamination beneath the Arroyo Chico and Mission Linen sites was modeled using the Analytical, Transient, 1-, 2-, or 3-Dimensional (AT123D) model, which was developed and is approved for use by the EPA. The AT123D model is capable of simulating the fate and transport of chemicals in groundwater under numerous different user-selected situations. The source of contamination can be finite or continuous and/or can be based on releases (outputs) from a vadose zone fate and transport model. Aquifer conditions and configurations were derived from existing groundwater data from wells in the nearby area, regional groundwater data, appropriate literature values, and/or regulatory defaults. Groundwater flow within AT123D is assumed to be steady and constant.

AT123D is able to take into effect volatilization, degradation, and adsorption under steady-state conditions. Contaminant transport via dispersion and advection can also be simulated. Contaminant concentrations at lateral and vertical distances from the source can be estimated over the stipulated simulation period. It should be noted that not all of these factors were applied to this screening-level assessment due to the limited amount of background data available and the nature of the perched aquifer.

Methodology and Assumptions

The following provides a summary of the inputs used to perform preliminary groundwater modeling for this project.

Aquifer Properties--

This assessment focused on the perched aquifer beneath the site, which was at a depth of approximately 90 to 100 feet bgs in the area. Information regarding this aquifer was obtained from logging and limited sampling of the two on-site monitoring wells and three Mission Linen monitoring wells completed in the perched aquifer. Information regarding the nature and extent of the perched aquifer in the vicinity of the site was limited, especially north of the site. As such, several conservative assumptions were made regarding the nature and extent of the perched aquifer, which would result in an overestimation of plume migration towards the potential receptor wells.

The modeling effort was conducted under the assumption that the perched groundwater layer present beneath the site is continuous from the Arroyo Chico area to the locations of the potable water wells. This is a conservative assumption given that information for the perched aquifer north of Broadway Boulevard is virtually non-existent, as shown in the reviewed document "A Preliminary Investigation of Groundwater Contamination in the Tucson Area" (Dulaney, 1992), and based on well installation information obtained from ADEQ after the preliminary modeling was performed (see Technical Memorandum 2 in Appendix N). This assumption overestimates off-site migration in the direction of the potable water wells if the perched aquifer is not continuous.

For this modeling run, the groundwater flow direction was assumed to be to the north based on preliminary calculations of groundwater elevations in the Arroyo Chico and Mission Linen monitoring wells, toward the western portion of the potable water well field. After this modeling run was performed, additional data were obtained that indicate a groundwater flow direction to the northeast, toward the eastern portion of the potable water well field. The hydraulic gradient was calculated to be 0.006 feet per foot based on preliminary groundwater elevation measurements in the Arroyo Chico and Mission Linen monitoring wells. This value may be high (producing conservative results), because the measured groundwater gradient on the Mission Linen site is reported as 0.001 to 0.003 feet per foot (*Phase 4 Remedial Investigation Workplan, Mission Industries,* by EMCON, November 1995). The model was also run at the 0.003 gradient, which is still the higher gradient value for the Mission Linen site.

The perched aquifer depth (thickness) was estimated to be 8.0 feet, which was the average depth of the perched layer based on geologic boring logs, groundwater monitoring well information, and regional hydrogeologic data. Based on the two Arroyo Chico monitoring wells installed by SCS, the perched aquifer thickness appeared to decrease towards the north, so this assumption is considered conservative. The perched aquifer width was estimated to be 2.0 miles, which was based on regional information that is very limited east of the project area.

The perched aquifer was assumed to be comprised of homogeneous clayey sand with an effective porosity of 0.24, which was derived from a default value for a typical sandy clay loam as presented in the AT123D model. The porosity analysis result for the 90-foot soil sample from monitoring well location WR-345 appeared anomalously high for this type of material, so the standard default was used in order to be more representative of the aquifer as a whole. The bulk density of the aquifer material (89.7 lbs/cf) was derived from a measured value from the 90-foot soil sample from well location WR-345. The hydraulic conductivity (or co-efficient of permeability) for the aquifer was derived from the same sample and was calculated to be 6.0E-06 cm/sec. The longitudinal, lateral, and vertical dispersivity of the aquifer were assumed to be 10, 1, and 1 meter, respectively, which were derived from AT123D default values from the low end of the range for sandy aquifers.

Source Properties--

The source of contamination for this modeling effort was assumed to be the existing groundwater plume beneath the Arroyo Chico project site and Mission Linen property associated with the Park-Euclid WQARF site, containing dissolved concentrations of PCE. The source was assumed to be instantaneous, indicating that all contamination had already reached groundwater and that no additional contamination will be added in the future. The model assumes that an instantaneous source is homogeneous, such that the contaminant loading is spread evenly throughout the plume. This is unlikely given heterogeneity of soils and aquifer materials. The plume was assumed to be a volume source.

The contaminant loading was determined by calculating an average concentration of PCE (16.75 milligrams per liter [mg/L]) within the Arroyo Chico and Mission Linen groundwater monitoring wells. Analytical data for the Mission Linen wells was from a sampling event performed in April 1993 (performed by others) and from the March 1998 sampling event for the Arroyo Chico site wells (performed by SCS). It was assumed that the average concentration was spread throughout the plume. The plume volume was estimated by deriving vertical and lateral limits to the plume and calculating a mass loading of PCE within the volume of aquifer defined by the limits. The PCE loading rate into the perched aquifer was calculated in this manner to be 2,656 kilograms.

The source location was defined on a coordinate grid established for the project, including "x", "y", and "z" coordinates. The "x" axis represents the direction of groundwater flow (to the north) along the plume centerline. The "y" axis represents the plane perpendicular to the direction of flow and defines the lateral spread of the plume in the cross-gradient directions. The "z" axis represents the vertical thickness of plume from the top of the aquifer to the maximum depth of contamination in the aquifer. The center of the plume was assumed to have "x" and "y" coordinates of 0,0.

Chemical Properties--

The only chemical modeled during this preliminary modeling effort was PCE, because it is the contaminant of most concern for the project area. The “retardation factor” that describes how PCE behaves in the subsurface was calculated by the model based on assumptions regarding biodegradation, diffusion, and adsorption. These assumptions are described below. The effect of the conservative assumptions used to calculate this factor results in an underestimation of the process of natural attenuation, whereby contamination concentrations in groundwater naturally decrease over time.

The decay constant for PCE was assumed to be zero, indicating that biodegradation of the contaminant will not occur. This is an extremely conservative assumption, because it is widely known that PCE and other organic solvents will degrade in an anaerobic saturated zone environment.

The distribution (adsorption) co-efficient of PCE was calculated using the chemical’s organic carbon partitioning co-efficient (0.66 cubic meters per kilogram) and the projected organic carbon content of the aquifer material (0.247 percent). The distribution co-efficient provides a measure of the amount of PCE that is likely to adsorb onto organic carbon in the aquifer.

The organic carbon partitioning co-efficient for PCE was obtained from appropriate literature values. The organic carbon content for the aquifer material was derived from AT123D model defaults for sandy aquifers. The value may actually be low because the perched aquifer contains clay material, which typically has a higher organic carbon content. This would result in an underestimation of the distribution co-efficient.

The molecular diffusion co-efficient of PCE (0.06968 centimeter squared per second) was derived from default values and represents the ability of the chemical to partition between the sorbed (liquid) and gaseous phases.

Simulation Period--

The AT123D model was run for a period of 500 years. Model results were derived at the following intervals for evaluation purposes: (1) 1 year, (2) 10 years, (3) 25 years, (4) 50 years, (5) 70 years, (6) 100 years, (7) 200 years, (8) 300 years, (9) 400 years, and (10) 500 years. Of special note is the 70-year simulation period that represents the averaging time for carcinogens (of which PCE is one) used in human health risk assessments. The 70-year period represents an average human lifetime.

Receptor Locations--

The identified potential receptor locations were five groundwater production wells located in the vicinity of the UA north of the site. Locations of these wells were provided by the COT, but details regarding well depths and screened intervals were not available for this assessment. The conservative assumption was made that the receptor wells were screened in the perched zone, and dilution due to co-production with the regional aquifer was not considered.

Receptor locations (potable water wells) were defined on the coordinate grid established for the project, including "x", "y", and "z" coordinates. The "x" axis represents the direction parallel to groundwater flow, the "y" direction is perpendicular to groundwater flow, and the "z" direction represents thickness of the modeled interval. Representative concentrations for each well, as predicted by the model, were derived from the well location at the top of the aquifer (z = 0). The five potable water wells evaluated in this study were represented by the following grid coordinates, representing distances from the middle of the source:

Well Number	X Coordinate	Y Coordinate	Z Coordinate
1	1,392	-304.5	0
2	1,436	65	0
3	1,109	174	0
4	935	914	0
5	500	848	0

The values are in meters from the center of the source. General location descriptions for each receptor are provided as a footnote to Tables 4 and 5.

Modeling Results

The results of this preliminary groundwater modeling study are presented on Tables 4 and 5. The values in Tables 4 and 5 represent the maximum aquifer concentrations at the well location for the time period specified. Table 4 contains the modeling results using the groundwater gradient of 0.006 feet per foot. Table 5 contains the modeling results using the groundwater gradient of 0.003 feet per foot. A value of zero indicates that the contaminant plume has not reached that well location by the time period specified.

CONCLUSIONS

On-Site Risks

Because no soil contamination was identified on the Arroyo Chico project site during this Phase II ESA, evaluation of risks associated with soil contamination was not performed. Although groundwater contamination was detected beneath the Arroyo Chico site, there are no drinking water wells or other potential pathways by which persons on the site could be exposed to contaminated groundwater. Therefore, detected groundwater contamination would not present health risks to persons occupying on the Arroyo Chico site and adjacent areas. However, if this groundwater contamination were to continue to migrate from the Arroyo Chico site to an off-site drinking water well, an exposure pathway could be completed, and health risks could exist for those obtaining drinking water from the well.

Off-Site Risks

To evaluate whether groundwater contamination could migrate from the Arroyo Chico site to the nearest downgradient groundwater production wells (located in the vicinity of the UA campus), a preliminary, screening-level groundwater modeling assessment was performed. This preliminary modeling study indicates that the possibility exists that groundwater contamination present at the Arroyo Chico and Mission Linen monitoring well locations could potentially impact the potable water wells to the north. Due to the preliminary nature of this modeling effort, potential health effects at these potable water wells were not evaluated.

Due to the very conservative nature of this screening-level modeling effort, the actual extent of migration and magnitude of downgradient concentrations may be significantly overestimated. One of the most significant assumptions is that the perched aquifer extends the full distance to the receptor wells; if this is not the case, it is possible that contamination in the perched aquifer would never reach the receptor wells. However, if groundwater in the perched aquifer flows over the edge of the aquitard where it apparently pinches out to the north, contamination present in the perched aquifer groundwater could be transported to the regional aquifer and potentially impact wells completed in that aquifer.

SECTION 8
ADDITIONAL GROUNDWATER ASSESSMENTS

OVERVIEW

Based on the results of the two stormwater infiltration assessments, the COT and County requested additional investigation of groundwater characteristics to provide more information on the potential for infiltration of stormwater at the site. Tasks included sampling and analysis of groundwater for VOCs, sampling and analysis of groundwater and surface water to perform tritium age-dating, installation and continuous logging of groundwater levels using electronic water level indicators (transducers) in both the perched and regional aquifers, collection of information for predictive modeling, and preparation of technical memoranda documenting the investigations.

SCS submitted the results of this phase of the groundwater investigation to the COT and County in a draft Technical Memorandum (dated October 29, 1999), draft Interim Status Report (dated February 4, 2000), a letter response to questions (dated February 18, 2000), and draft Technical Memorandum 2 (dated September 20, 2000). The final Technical Memorandum 1, which documents the purging and sampling of the nested wells at location WR-347, and final Technical Memorandum 2, which discusses the findings of the groundwater investigation, are included in Appendices M and N, respectively. The discussion below is a summary of the investigations documented in the two Technical Memoranda.

GROUNDWATER SAMPLING AND ANALYSIS

<u>Depths to Groundwater</u>

Depths to groundwater were measured in the two pairs of nested site wells by SCS personnel using a hand-held electronic water level indicator on September 20, 1999. Measured depths to groundwater were 95.43 feet bgs in WR-347A and 94.52 feet bgs in WR-345A in the perched aquifer wells, and 203.78 feet bgs in WR-347B and 199.28 feet bgs in WR-345B in the regional aquifer wells. The water levels showed an increase from previous measurements in February 1998 in the perched aquifer wells and showed a decrease in the regional aquifer wells.

There was a 6.26-foot difference in groundwater elevation calculated between the two perched aquifer well locations, with WR-347A generally hydrogeologically upgradient from WR-345A. There was a 2.77-foot difference in groundwater elevation calculated between the two regional aquifer well locations, with WR-347B generally hydrogeologically upgradient from WR-345B. Water level measurements, groundwater datum elevations (surveyed at the tops of the well casings), and calculated groundwater surface elevations for the two perched and two regional wells are summarized in Table 1 in Technical Memorandum 2.

<u>Groundwater Sampling and Analysis</u>

The perched and regional aquifer wells located at WR-347 were purged and groundwater samples were collected by SCS on September 20, 1999. The two groundwater samples were analyzed for VOCs and semi-VOCs. The laboratory analytical results detected PCE (160 μg/L), acenaphthene (9.1 μg/L), and bis (2-ethylhexyl) phthalate (45 μg/L) in groundwater collected from the perched aquifer well (WR-347A), and bis (2-ethylhexyl) phthalate (7.7 μg/L) from the regional aquifer well (WR-347B). The concentration of PCE detected in the sample from perched aquifer well WR-347A exceeded the AWQS of 5 μg/L. No AWQS for acenaphthene and bis (2-ethylhexyl) phthalate have been established. Copies of the water sampling logs and laboratory analytical report are included in Technical Memorandum 1.

These results were similar to the previous analytical results obtained for groundwater samples collected by SCS from these two wells in February 1998. No on-site source of these contaminants has been identified during this or previous investigations. The Park-Euclid WQARF site is the likely source of the contaminants detected in groundwater samples collected from the subject site wells. An ADEQ map showing the location and approximate boundaries of the Park-Euclid WQARF site groundwater plumes is included in Attachment 3 of Technical Memorandum 2.

TRITIUM AGE DATING

One sample of surface water was also collected September 20, 1999 by SCS from stream flow at the bottom of the Arroyo Chico channel at the intersection of the channel with the Fremont Avenue alignment. The surface water sample and groundwater samples from wells WR-347A and WR-347B were shipped to the University of Miami Tritium Laboratory and were analyzed for tritium. The laboratory analytical results were 12.6 TU for the sample from WR-347A, 0.05 TU (below the laboratory detection limit of 0.1 TU) for the sample from WR-347B, and 4.12 TU for the surface water sample. A copy of the laboratory analytical report is included in Attachment 4 of Technical Memorandum 2.

As discussed in Technical Memorandum 2, the source of worldwide atmospheric tritium was the nuclear testing performed in the 1950s, and an additional source in the site area was industrial releases of tritium in the late 1970s from the American Atomics facility located hydrologically upgradient (generally east) of the site. Because of tritium's short half-life of approximately 12.5 years, the concentration of tritium in water can be used as a tracer to determine when water was in contact with the atmosphere, and the rate at which water travels through the surface and enters groundwater. Average atmospheric tritium concentrations for the Northern Hemisphere of the United States are depicted in Figure 2 in Technical Memorandum 2; this figure is discussed in detail in Technical Memorandum 2.

The results of the tritium age-dating of the perched aquifer, regional aquifer, and surface water at the project site indicate the following:

- The regional aquifer contains groundwater that is at least 50 years old;

- Groundwater in the perched aquifer exhibits an average age of at least 10 years (and less than 30 years); and

- The two aquifer systems are not in hydraulic communication.

The probable concentration of tritium in surface water at the time the water entered the subsurface can be calculated using the half-life of tritium. Uncertainty as to the frequency and concentrations of tritium releases attributable to the American Atomics facility makes it difficult to determine the volume of tritium that may be retained in the vadose zone above the perched aquifer. If residual soil moisture within the vadose zone contains tritium released from American Atomics, mixing of recharge water with vadose zone moisture could cause the calculated age of the groundwater to be older than the actual age of the groundwater; therefore, the age of the perched aquifer groundwater could be less than the calculated minimum age of 10 years.

MONITORING OF GROUNDWATER ELEVATIONS USING TRANSDUCERS

Overview

Continuous monitoring of groundwater elevations in perched aquifer well WR-347A and regional aquifer well WR-347B was performed using electronic water level indicators (transducers) from December 10, 1999 through July 28, 2000. The resulting hydrograph data allowed for the observation of responses of the perched aquifer to precipitation and stream flow during the period of record and responses of the regional aquifer to local pumping.

Analyses of the hydrograph data obtained from the transducers installed in the two wells centered upon five goals, including assessment of general trends and definition of large-scale variations in the water levels of both the perched and regional aquifers; quantification of the effects of barometric pressure changes through the determination of barometric efficiencies (B_E); investigation of the influence of groundwater pumping at the UA upon the project site water levels; and determination whether precipitation events are a significant source of recharge to the perched aquifer.

Water Level Data Collection Methodology

SCS installed Global Water WaterLogger (WL14) electronic water level indicators (transducers) in perched aquifer well WR-347A and regional aquifer well WR-347B on December 10, 1999. The transducers recorded water level elevations continuously at 15-minute intervals until July 5, 2000 in WR-347B and July 28, 2000 in WR-347A (when the transducers were removed), except for brief periods of transducer malfunction, anomalies, and/or data gaps, as discussed in Technical Memorandum 2. The hydrograph of water levels for the period of record for each well is included on Figures 3a and 3b in Technical Memorandum 2. Groundwater levels for the WR-347 and WR-345 nested wells were also periodically measured manually using a hand-held electronic water level indicator in order to double-check and calibrate the data recorded by the transducers; these groundwater levels are listed in Table 1 in Technical Memorandum 2.

Water Level Results – Perched Aquifer

Cyclical fluctuations and a general downward trend were recorded for the water elevations of perched well WR-347A over the 232 days covered by this investigation. The total variation in measured water levels was approximately 2 feet (excluding an anomalous peak in the data and aquifer recovery after sampling). Water levels gradually fell from December 10, 1999 until January 12, 2000, when there was a rapid increase of approximately one-half foot in one hour. This rapid rise in water level occurred 10 days after a rainfall event of 0.17 inches was recorded at the UA weather station. Although other rainfall events occurred in February and June, no other hydrograph fluctuations similar to the January 12 event were recorded.

No other hydrograph characteristics of note were observed for the perched aquifer, except for an anomalous peak in mid-February, which is discussed in more detail in Technical

Memorandum 2. Because of unknown factors, such as vadose zone antecedent moisture conditions, the area receiving rainfall, and the effects of local lithology on channeling groundwater flow, it is difficult to correlate one rainfall event with a change in water level using this limited data set. Thus, the rate at which precipitation is recharging the aquifer cannot be determined based on the hydrograph data.

Water Level Results – Regional Aquifer

The transducer data for the regional aquifer also showed cyclical fluctuations over an approximately 0.5-foot range and a general downward trend in the water levels in well WR-347B. Overall, the regional water levels, while more variable, declined at a slightly slower rate than the perched water levels. Average water levels rose slightly from late December 1999 to early January 2000, and then generally declined. The total variation in measured water levels was approximately 2.13 feet (excluding an anomalous low point in the data corresponding to the time of a manual water level measurement, discussed in more detail in Technical Memorandum 2). The groundwater elevations in the regional aquifer did not appear to exhibit any response to the apparent recharge events observed in the perched aquifer data. This is to be expected due to the lack of hydraulic connectivity between the perched and regional aquifers in the site area that was indicated by the tritium age data.

PERCHED AQUIFER CHARACTERISTICS

On May 17, 2000, consultants contracted by ADEQ performed groundwater sampling of the site wells as part of activities associated with investigation of the Park-Euclid WQARF site. SCS observed the response of the perched and regional aquifers to the purging and sampling event by measuring groundwater elevations using a hand-held electronic sounder before, during, and after purging and sampling of the groundwater, and by examining the transducer data following reinstallation into the wells.

Although the water levels in WR-347B responded too quickly to determine aquifer properties for the regional aquifer, the transducer in WR-347A monitored the recovery of perched water levels to pre-purging conditions. Therefore, groundwater elevation data obtained during this task could be used to calculate aquifer characteristics for the perched aquifer. Using the Bouwer-Rice solution for slug tests in an unconfined aquifer, a hydraulic conductivity of 2.6 x 10^{-5} cm/sec was determined for the perched aquifer.

The response of both groundwater monitoring wells to this purging and sampling event is evident on the Figure 3b hydrograph in Technical Memorandum 2. It should be noted that the slight increase in water levels in the perched aquifer following recovery was due to a small difference in the seating of the transducer following replacement back into the well, and not an increase in the water level.

COLLECTION AND INTERPRETATION OF SUPPORTING DATA

Site Area Geology and Hydrogeologic Conditions

The ephemeral Arroyo Chico channel is located within the alluvial Tucson Basin portion of the Upper Santa Cruz River drainage basin. The Arroyo Chico flows generally west-northwest towards the Santa Cruz River, which flows northward in this portion of the Tucson Basin. The surface topography is typical of arid alluvial fan depositional environments, sloping west and northwest towards the Santa Cruz River. Two saturated groundwater zones have been identified in the vicinity of the site: a perched aquifer at approximately 96 feet below land surface, and the regional aquifer at approximately 200 feet below land surface.

The approximately 8-foot saturated thickness of the perched aquifer rests on an aquitard consisting of fine-grained clay/silt. The perched aquifer has been observed to extend south and west of the site, but apparently pinches out less than a mile north of the site. This type of depositional setting exhibits spatial and temporal variability in unsaturated flow, with recharge most likely flowing within preferential flow pathlines. Perched groundwater held above the clay/silt layer aquitard would be expected to drain down to the deeper regional aquifer along the edges of the aquitard where the clay/silt layer pinches out. The areal extent and configuration of the pinch-out zone would be expected to control groundwater flow direction, as well as the capacity of the aquifer to maintain a head of water above the aquitard. Groundwater elevations suggest that the perched aquifer flows and drains generally to the northeast in the area of the project site. Records reviewed for wells in the site area (shown on Figure 5 in Technical Memorandum 2) did not identify water supply wells for the perched aquifer.

The deeper groundwater aquifer is regional in extent and exhibits semi-confined to confined aquifer conditions. The groundwater flow in this aquifer in the vicinity of the project site is generally to the northeast. The regional aquifer provides water supply to the City of Tucson. Heavy withdrawal from the UA water supply well field north of the site is believed to influence the direction of regional groundwater flow in the site area.

Localized recharge of groundwater, such as from the washes and channels crossing the Tucson Basin, is considered the most important source of natural recharge in arid and semi-arid climates. The recharge rate depends on factors such as antecedent moisture content, preferential flow pathlines within the alluvial material, volume of rainfall, and volume of water flowing or ponding within the channel. Velocities of 1.9 to 9.0 feet per day have been reported for wetting front migration from these recharge zones. Isotope studies of recharge in the Rillito River have measured an approximate 2-year travel time through the vadose zone at a rate of approximately 0.18 feet per day.

Rainfall Data

Rainfall data for the Arroyo Chico area, recorded at a weather station located at the UA approximately 0.75 mile directly north of the Arroyo Chico project site, was obtained for the period of investigation, and is shown on the hydrographs in Figures 3a and 3b in Technical

Memorandum 2. Rainfall data was reviewed to evaluate whether there were correlations between rainfall and water level data collected from the site wells.

Rainfall data for the year preceding installation of the transducers in the wells, as depicted on Figure 6 in Technical Memorandum 2 for January through December 1999, indicated that a total of approximately 7.5 inches of rain was recorded at the UA weather station during the 1999 monsoon season; the next recorded rainfall, measured at 0.17 inches, occurred on January 2, 2000. Rainfall between March 5 and 7, 2000 totaled approximately 0.94 inches and monsoon season rainfall from June 17 through 30, 2000 totaled approximately 1.97 inches. Seven minor rainfall events of less than 0.1 inches occurred in late February, late March, and in July 2000.

The perched aquifer well WR-347A hydrograph showed a sharp rise in water levels on January 12, 2000. The water levels peaked by January 21 and were followed by a slow decay of groundwater elevation over time. The shape of the hydrograph for this rapid rise in water level on January 12 and the subsequent gradual decline is typical of a response curve for a spontaneous recharge event. The most recent rainfall event prior to January 12, 2000, other than the minor precipitation received on January 2, was at the end of the monsoon season in September 1999. If the January 12, 2000 recharge event recorded in perched aquifer well WR-347A resulted from precipitation that occurred during the 1999 monsoon season, the time of travel would appear to be approximately 5 months.

No other apparent recharge response was evident on the hydrograph through July 28, 2000, the end of the project monitoring period. The limited period of hydrograph data makes it difficult to discern a relationship between a specific rainfall event and a groundwater recharge response. However, it is evident that recharge to the perched system occurred from September 1999 through January 2000, including the January 12 recharge event. It is probable that the rise in the groundwater elevation represents recharge to the perched aquifer by drainage of water from the Arroyo Chico channel.

Barometric Pressure Data

Barometric pressure data, recorded at 5-second intervals at a weather station located at the UA approximately 0.75 mile directly north of the Arroyo Chico project site, was obtained for the period of investigation. The barometric pressure data were processed to obtain readings at 15-minute intervals in order to correspond to the sampling frequency of the transducers; the data are shown on the hydrographs in Figures 3a, 3b, and 7 in Technical Memorandum 2. It should be noted that the barometric pressure data is plotted as inverted, which allows for a visual comparison of barometric pressure against water level response; i.e., when pressure drops, such as seen in mid-March on Figure 7 in Technical Memorandum 2, the over-plot on the hydrograph depicts a peak.

Barometric efficiency (B_E) is described as the change in water level per unit change in atmospheric pressure (both values expressed in terms of height of water). The average B_E was determined for each aquifer in order to “remove” the effect of changing atmospheric conditions upon water levels; further discussion of this process can be found in Technical Memorandum 2. Ideally, this method will produce a straight line if water level fluctuations are driven purely by changes in barometric pressure. However, it is clear that correction for barometric pressure does not explain the magnitude of the variations in the water levels.

Water level fluctuations of approximately 0.1 foot were observed in the aquifers in response to barometric pressure changes. Both the perched and the regional aquifers appeared to have responded to a rapid barometric pressure drop recorded in mid-March. B_E values of 0.15 and 0.9 were used in the calculations for the perched and regional aquifers, respectively. Because the perched aquifer is unconfined and open to variations in atmospheric pressures, it is expected that the response of water levels to barometric pressure fluctuations would be represented by subtle fluctuations in water levels on the hydrograph. Figure 7 in Technical Memorandum 2 presents the perched aquifer water levels for the period between March 5 and April 2, 2000 corrected for barometric pressure fluctuations; at the scale of the figure, the correction appears to be minor.

Water levels in wells completed in confined to semi-confined aquifer systems, such as the regional aquifer, are expected to be more responsive to atmospheric barometric pressure changes. Because the focus of the investigation was on the perched aquifer, dampening effects of barometric pressure on water levels were not plotted for the regional aquifer.

Other factors, such as earth tides and daily atmospheric heating and cooling, can also affect measured water levels. Earth tides are similar to the oceanic tides and are driven by the same lunar and solar gravitational forces. Daily atmospheric heating and cooling causes corresponding changes in barometric pressure over approximately 12-hour cycles. This time frame is substantially less than that caused by changing weather conditions. After the barometric efficiency corrections were performed, the perched aquifer data was corrected for diurnal fluctuations by applying a 24-hour moving average to the perched aquifer water level data. Figure 7 in Technical Memorandum 2 presents the results of dampening diurnal fluctuations on the perched aquifer groundwater elevations.

University of Arizona Well Pumping Data

Groundwater pumping at six production wells in the UA well field was investigated as a possible influence upon water levels in the regional aquifer; these wells are shown on Figure 1 in Technical Memorandum 2. UA pumping data is summarized on Table 2 and Figures 8 and 9 in Technical Memorandum 2, and Figure 9 compares the pumping data to the groundwater elevation data for the regional aquifer.

As shown on Figure 9, there appears to be a weak inverse relationship between pumping rate and the general trend in the regional aquifer water levels, but additional monitoring would be required in order to elucidate any correlation. The UA well field pumping appeared to have a minimal short-term impact on groundwater level fluctuations at the site, but it is possible that groundwater pumping in the proximity of the site could contribute to the long-term decline in water levels evident in the hydrographs shown on Figures 3a and 3b in Technical Memorandum 2. There is no evidence of pumping influence on the perched aquifer.

USGS and ADWR Research of the Rillito River

The United States Geological Survey (USGS) and ADWR have been funding extensive ongoing investigations of infiltration and recharge of groundwater at the Rillito River, located approximately 4.5 miles north of the Arroyo Chico. Various study methods, such as analysis of water for environmental tracers, micro-gravity surveys, and temperature profiling have been incorporated into the investigations.

Information obtained from the USGS and ADWR investigations at the Rillito River indicated that based on chemical and isotopic age calculations, the actual travel time of a particle of water through the subsurface is at the rate of an estimated 0.18 feet per day, or approximately 2 year travel time. However, hydrograph responses to individual rainfall events were reflected approximately 30 days after a substantial rainfall. This 30-day response to rainfall may be attributed to a "piston" pressure flow response, which causes infiltrated water to push downward on water already present in the vadose zone, thus inducing a recharge response at the water table.

COMPARISON OF SITE INVESTIGATION DATA WITH OTHER TUCSON AREA DATA

If it is assumed that the approximately 90 feet of vadose zone beneath the Arroyo Chico channel is similar to that beneath the Rillito River channel area, a particle of water could take a minimum of approximately 16 months to reach the water table. However, the "piston" pressure flow response could induce a recharge response in the groundwater levels in as little as 20 days.

Measured wetting front velocities of 1.9 to 9.0 feet per day have been observed for other studies performed in the Tucson area. Using these values to calculate the movement of groundwater through the vadose zone at the site, the estimated time for the observed hydrograph response to a recharge event would be within 10 to approximately 48 days. Comparing this estimated time of travel to rainfall events recorded at the UA weather station in early January, early March, and mid to late June, there should have been responses evident on the hydrograph for WR-347A sometime between mid January and mid February, mid March to mid April, and late June to early August. No hydrograph responses were identified during the monitoring period.

Review of the hydrograph response for the January 12, 2000 recharge event in site well WR-347A, in context with the water level fluctuations preceding the rapid increase in water levels, indicates that a series of discrete volumes of recharge may have been entering the perched aquifer prior to this date. This observation is consistent with the characterization of "piston" flow discussed above. If the general rise in groundwater elevations observed between September 1999 and January 2000 represents a series of discrete "piston" recharge events following the 1999 monsoon season, the January 12, 2000 rise might represent the end of recharge attributable to the monsoon rainfall.

SECTION 9
PREDICTIVE GROUNDWATER MODELING

OVERVIEW

By request of the COT and County, SCS retained Daniel B. Stephens & Associates (DBS&A) to perform predictive groundwater modeling to evaluate the effect of infiltration of stormwater at the locations of the proposed stormwater detention Basin 1. The objective was to estimate the difference in infiltration for scenarios without the proposed basin (existing conditions) and with the proposed basin (post-construction); DBS&A refers to these as the "without-project" and "with-project" scenarios. Proposed Basin 1 was used for this study because it is downgradient of the other proposed basins, and will experience longer periods of saturation during stormwater flow events. Tasks performed included compilation and analysis of existing data, development of a conceptual hydrologic model based on the existing data, construction of numerical models, and performance of simulations to quantify potential infiltration. The preliminary investigation results and a response to comments were reported in August 2001.

By request of the COT and County, following discussions and meetings regarding the modeling results, revised grading plans for the basin, and changes requested by the County, additional modeling was performed. Along with the original objectives, additional objectives for the subsequent modeling were to estimate the total amount of infiltration for each model scenario for different flood events, identify design elements that would minimize groundwater recharge for the scenarios with the proposed basin, and to evaluate the potential impacts on the amount of transpiration. The final DBS&A report, dated January 2001, is included in Appendix O. Figure 1 in the DBS&A report shows the locations of the proposed basins.

Data used to develop the conceptual model included existing and proposed land surface elevations, flow hydrographs, estimated ponding elevations, soil hydraulic properties, and groundwater level measurements. The numerical model was constructed based on the conceptual model. The County provided the proposed land surface elevations and surface water modeling data for the basin to DBS&A. Information used to establish the hydrogeologic setting for the site area was obtained by reviewing data collected by SCS, Maxim, and Montgomery during the previous work performed for the Arroyo Chico Multi-Use Project investigation and by review of documents at ADEQ for investigations of the Park-Euclid WQARF site; Tables 1 and 2 in the DBS&A report show available hydraulic conductivity and measured water content data for the site area. The DBS&A report includes a discussion of the hydrogeologic setting and a cross section (shown in Figure 2) of the proposed Basin 1 area.

MODELING APPROACH

The computer code HYDRUS-2D was selected by DBS&A to perform the computer modeling. This code uses a finite element approach to solve the Richards equation for water flow in variably saturated media, and allows for transient variations in boundary conditions. The modeling profile for the preliminary investigation used a 300-meter cross section through proposed Basin 1. However, the subsequent modeling profiles were based on average (or representative) cross sections rather than a single cross section, which DBS&A felt would better represent conditions in the basin. The methodology DBS&A used to construct the representative cross sections is provided in Appendix A of their report.

Boundary conditions used for the simulations include no-flow, variable pressure head (to simulate ponding), and prescribed pressure head boundaries (see Figures 3 and 4 in the DBS&A report). DBS&A originally used a depth of 8 meters below the base of the Arroyo Chico channel for the lower model boundary, but by request of the County, the depth was extended to the top of the perched aquifer. The methodology for calculating the transient ponding elevations for each scenario is provided in Appendix B of the DBS&A report. Relatively fine finite element meshes were required to perform the simulations. A finer mesh was developed for the with-project scenario to facilitate modeling of low-permeability material along the basin floor. The finite element meshes developed for both scenarios are discussed in the DBS&A report (see Figures 5 and 6).

Hydraulic parameters required for the model input included residual and saturated water contents, saturated hydraulic conductivity, and fitting parameters for the soil-water retention and unsaturated hydraulic conductivity functions, which were derived using the analytical model of van Genuchten. Because there was little to no site-specific data available for the above parameters, these values had to be estimated. The DBS&A report discusses the methodology for selecting the hydraulic properties used in the model.

Three separate surface water flow events were simulated for each of the two model scenarios: the 100-year, 10-year, and 2-year flow events. Ponded infiltration into the subsurface soils was simulated during the period of saturated conditions. Each simulation was run for a period of 50 years. Additional simulations were performed to evaluate the sensitivity of the model results to variations in the initial conditions. Use of the representative cross section for the basin allowed use of a scaling factor to convert the modeled infiltration to the total amount of infiltration, as discussed in the DBS&A report.

SIMULATION RESULTS

The computed amounts of infiltration for the simulations are provided in Table 3 in the DBS&A report. The with- and without-project model runs included a base case, which included one soil material (Soil Material 1) and assumed a zero gradient initial condition. The second without-project model runs used initial conditions (i.e., starting pressure heads) based on a previous 100-year event that occurred 365 days prior to the simulation. The second with-project model runs assigned a low hydraulic conductivity material (Soil Material 2) to the basin floor below the elevation of the 2-year floodplain.

The base case model runs show infiltration is consistently greater for the with-project scenario than for the existing without-project conditions. For all three flow events (100-, 10-, and

2-year), the ratio of the with- to without-project total cumulative infiltration ranges from 2.8:1 to 3.0:1. The with-project scenarios that simulated usage of a low hydraulic conductivity material on the basin floor show that partially lining the basin could significantly limit infiltration to amounts less than or generally equivalent to the without-project scenario infiltration amounts. Evaluation of the sensitivity of the without-project model results found that higher pressure heads near the surface (simulating a previous flow event) do not significantly affect the computed infiltration volumes, but the rate of wetting front migration is strongly influenced by the initial distribution of pressure heads.

Both the with- and without-project scenarios show that most of the infiltration occurs in the first 8 hours of each flow event; plots of cumulative infiltration versus time are included in Appendix C of the DBS&A report. Plots depicting early-time wetting front migration of modeled water content at simulation times of 0.25, 1, and 5 days for the different scenarios are included in Appendix D of the DBS&A report. The with-project scenarios that use a reduced-permeability layer on the basin floor shows that the wetting front is impeded in the central portion of the basin, and for the larger flow events, infiltration occurs at the higher basin elevations above this soil level. Selected pages of the HYDRUS-2D input and output files for the 100-year event simulations are included in Appendix E of the DBS&A report.

All model simulations indicated that it takes more than ten years for the wetting front to reach the perched water table. However, this arrival time calculation is highly sensitive to modeling assumptions, including the initial conditions (i.e., starting pressure heads or water contents) and unsaturated hydraulic properties, as well as lithologic heterogeneity of the subsurface soils (such as clay lenses). Because there is insufficient site-specific information that can be used to determine the extent of low-permeability zones (or areas of preferential flow), relatively few soil water content measurements near the Arroyo Chico channel, and no measurements of unsaturated hydraulic properties, DBS&A does not recommend using the existing models to predict particle travel times or wetting front arrival times for depths greater than a few meters.

According to DBS&A, it was impossible to accurately quantify the overall influence of vegetation on the water balance for the project scenarios because there are no soil parameter data for vegetated areas. Vegetated soils generally have permeabilities an order of magnitude higher than non-vegetated soils due to macropores and other soil structures created by plants.

CONCLUSIONS

The model simulations suggest that construction of the proposed stormwater detention basins will cause increased infiltration in the vicinity of Basin 1. Increased infiltration of stormwater will increase the amount of recharge to the perched aquifer at the site. DBS&A explicitly states that the simulations should not be used to estimate wetting front migration rates or particle travel times through the vadose zone beyond a few meters depth due to data limitations for the site. Because only the near-surface area will be altered by construction, the travel time will be basically the same for both scenarios given the same volume of water entering the system.

If the project goal is to keep the net infiltration of water the same for the constructed basin as for the existing site conditions, DBS&A states that the basin bottom will need to be lined to the high water level of the 2-year flood event with a reduced permeability material consisting of compacted soil, soil amendments, or synthetic material. Landscaping and vegetation are not compatible with lined areas. The area requiring reduced permeability can also be minimized by altering the footprint of the 2-year flood event using berms or terraces in order to maximize the landscaping and vegetated areas.

Additional discussion of the results of the groundwater modeling performed for the site and the limitations and assumptions is included in Section 10.

SECTION 10
DISCUSSION OF STORMWATER INFILTRATION, GROUNDWATER ASSESSMENT, AND GROUNDWATER MODELING RESULTS

RESULTS OF INVESTIGATIONS

Two infiltration investigations, groundwater assessments, and predictive groundwater modeling were performed as part of the Arroyo Chico Multi-Use Project Phase II ESA investigation with regard to the stormwater detention basins proposed for the site. The results of these investigations are discussed in Sections 4, 5, 8, and 9 of this report. Estimations for depths and rates of stormwater infiltration and groundwater ages obtained during these investigations were as follows:

- Maxim performed percolation tests at the site by measuring water level declines in test borings (discussed in Section 4). Using very conservative assumptions, Maxim estimated that the potential depth of saturation beneath the proposed basins ranged from 48 to 61 feet bgs for a 36-hour holding period, 32 to 56 feet for a 12-hour holding period, and 13 to 45 feet for a 6-hour holding period.

- Montgomery performed double-ring infiltrometer tests and “small basin” percolation tests in within the Arroyo Chico channel, and monitored the infiltration of stormwater in naturally occurring depressions in well-lithified caliche in the channel to project the potential depth of wetting front movement below the basins during a 36-hour period of stormwater detention (discussed in Section 5). Montgomery estimated that the representative average infiltration capacity for the Arroyo Chico site would be between 3 to 10 feet per day, and estimated that based on a fillable porosity of about 20 percent, the projected depth of wetting front movement would be 15 to 50 feet per day, or 22 to 75 feet for the maximum 36-hour detention time for the stormwater.

- SCS and WMCI performed tritium age-dating of the perched aquifer, regional aquifer, and surface water at the project site (discussed in Section 8). The results indicated that groundwater in the regional aquifer is at least 50 years old, groundwater in the perched aquifer exhibits an average age of at least 10 years (and less than 30 years), and the two aquifer systems are not in hydraulic communication.

- Water levels were monitored by SCS for seven months using transducers in one perched and one regional aquifer well at the site (discussed in Section 8). Because of unknown factors, such as vadose zone antecedent moisture conditions, the area receiving rainfall, and the effects of local lithology on channeling groundwater flow, the one apparent recharge event could not be correlated to one specific rainfall event and the rate at which precipitation is recharging the aquifer could not be determined based on the limited hydrograph data set.

- WMCI evaluated data from other investigations performed within the Tucson area to compare to conditions at the site (discussed in Section 8). Velocities of 1.9 to 9.0 feet per day have been reported for wetting front migration from other recharge zones in the Tucson area. Using these values to calculate the movement of groundwater through the vadose zone at the site, the estimated time for the observed hydrograph response to a recharge event would be within 10 to approximately 48 days. Comparing this estimated time of travel to rainfall events in the site area, there should have been groundwater responses sometime between mid January and early August 2000; however, no hydrograph responses were identified for the site well during this monitoring period. The hydrograph response for the apparent recharge event recorded January 12, 2000 may have resulted from the end of discrete "piston" recharge events attributable to the 1999 monsoon season rainfall.

  Investigations of recharge in the Rillito River north of the site have measured an approximate 2-year travel time through the vadose zone at a rate of approximately 0.18 feet per day based on isotope studies; however, "piston" pressure flow responses were apparently reflected in hydrographs approximately 30 days after substantial rainfall events. If it is assumed that the vadose zone beneath the Arroyo Chico is similar to that beneath the Rillito River, a particle of water could take a minimum of approximately 16 months to reach the water table, but the "piston" pressure flow response could induce a recharge response in the groundwater levels in as little as 20 days.

- DBS&A performed predictive groundwater modeling to evaluate the effect of infiltration of stormwater at the location of the proposed stormwater detention Basin 1 at the site for scenarios without the proposed basin (existing conditions) and with the proposed basin (after construction), as discussed in Section 9. The model runs also included simulations for a partially lined basin.

  The results showed that infiltration was consistently greater for the proposed basin than for the existing site conditions, with the total cumulative infiltration ratio ranging from 2.8:1 to 3.0:1. The scenarios that simulated partial lining of the basin floor showed that infiltration was significantly limited to amounts less than or generally equivalent to the existing condition infiltration amounts. The model simulations showed that most of the infiltration occurred in the first 8 hours of each flow event whether the basin was in place or not.

DISCUSSION OF RESULTS AND LIMITATIONS

<u>Discussion</u>

The results from the investigations discussed in this report are limited by the paucity of site-specific soil and groundwater information, including (but not limited to) the extent of moderately- to well-lithified sediments, soil moisture contents, lithologic heterogeneity, unsaturated hydraulic properties, locations of preferential flow pathlines, and long-term groundwater levels. Actual stormwater infiltration rates over the entire basin area would likely be much less than was calculated due to factors including (but not limited to) air entrainment, evapotranspiration, siltation, and compaction. The collection of additional data would require extensive additional soil and groundwater investigations. Without additional data, the results discussed in this report must be viewed as conservative estimates based on the limited available data. Limitations and assumptions for the investigations are discussed below.

1. The scale of the infiltration tests were very small in comparison with that of the proposed basins and there was a very wide range of results for the infiltration rates obtained during the testing (nearly 0 feet per day up to 40 feet per day), which made development of a reasonable average infiltration rate or even a range of rates difficult.

2. The infiltration testing methodologies used in this investigation assumed that nearly all water percolated in a vertical direction; however, the methodologies could not completely eliminate the effects of lateral percolation. Lateral flow was observed in some of the double-ring infiltrometer and small basin tests and likely occurred to some degree during the test boring percolation tests. Lateral flow during the tests would result in an overestimate of the steady-state infiltration rate. Actual vertical infiltration depths would be less (at least 10 percent) than that calculated directly from percolation test boring data because lateral spreading over an entire basin surface would be limited to the basin edges and because the vertical permeability of soils is much lower than the horizontal permeability.

3. The actual continuity and extent of moderately- to well-lithified sediments (such as caliche) throughout the proposed basin areas and the degree of heterogeneity of sediments below the basins is not known. Variations in the lithology (such as the presence of clay lenses) and lithification throughout the vadose zone can greatly impact flow pathways, and can impede or aid infiltration depths and rates. For example, if excavation of the basins results in removal of well-lithified soil layers, infiltration in those areas could be increased.

4. Fine-grained sediments and organic materials are likely to settle out of stormwater and accumulate on the basin floors after several filling cycles, which can greatly reduce the infiltration capacity. For example, the Los Angeles Department of Public Works (LADPW) Water Recharge Division has extensive experience with attempting to operate exhausted gravel quarries as infiltration basins. The LADPW has found that after the first season, silts and clays tend to clog the pores in the bottom of the basin, and unless the basin floor is disked or scraped, vertical percolation through the basin floor ceases. Therefore, practically all percolation occurs horizontally through the sides of the pit, until the sides also become clogged. Since the proposed site basins will not be disked or scraped to eliminate the clogging effect of silts and clays, percolation rates (and the resulting depth of saturation) would likely decrease significantly with time.

5. Estimates for infiltration and wetting front movement were made by Maxim and Montgomery based on the maximum predicted depth of water for a detention time of 36 hours. Most storms would result in much smaller volumes of water stored over shorter periods of time, resulting in less infiltration. In addition, these estimates were prepared for a single basin-filling event. Repeated basin-filling events would result in infiltration volumes that are essentially additive, and the fillable porosity would be reduced, so that a nearly steady-state wetting pattern could develop between the land surface and groundwater, which would result in increased infiltration.

   None of the LADPW basins (many of which are in very porous sand and gravel deposits that are more permeable than soils beneath the Arroyo Chico project area) percolate more than 4 feet per day, and this rate is only achieved when the entire soil column between the basin floor and the groundwater surface is saturated. Using the 4 feet per day maximum infiltration rate in the vertical direction and calculating for the proposed site conditions, 6 feet of water could enter the subsurface over 36 hours (1.5

days) of percolation. Assuming the water-retaining capacity of the soil is 10 percent, the wetting front could potentially move approximately 60 feet downward.

It is emphasized that this calculation is conservative since it assumes saturated flow, which is not likely to occur at the Arroyo Chico. Between infiltration events, the soil will dry out, as demonstrated by the fact that Tucson soils are typically well below their moisture retention capacity. When unsaturated flow conditions exist (as is likely at the Arroyo Chico), not all of the soil pore space can be occupied by water, so the infiltration rate is restricted from its theoretical maximum by air trapped in the soil.

6. The actual historic atmospheric tritium levels at the site are not known. It is known that there were significant releases of tritium to the atmosphere in the Tucson area in the late 1970s. If the age dates for the perched aquifer were adjusted to account for additional tritium in the atmosphere in the Tucson area, the age of the water in the perched aquifer could be less than the calculated minimum age of 10 years.

7. Only one apparent recharge event in the perched aquifer occurred during the seven month period of groundwater level monitoring in the site wells using transducers. Therefore, this period of time was not long enough to determine correlations between specific rainfall events and hydrograph responses to recharge for the wells. Comparing potential infiltration rates and “piston” response times for other locations in Tucson to the site is a useful exercise; however, it must be emphasized that it is *only* an exercise, because it is not known how vadose zone conditions at the site compare to conditions at the other locations.

8. The groundwater predictive model simulations showed that with the basins in place, infiltration was greater than for the existing conditions. The modeling was subject to similar data limitations as the other investigations performed for the site project. Evaluation of the model sensitivity found that higher pressure heads near the surface (simulating a previous flow event) do not significantly affect the computed infiltration

volumes, but the rate of wetting front migration is strongly influenced by the initial distribution of pressure heads. The overall influence of vegetation on the water balance for the project scenarios could not be accurately quantified because there are no soil parameter data for existing vegetated areas, which will generally have permeabilities an order of magnitude higher than non-vegetated soils due to macropores and other soil structures created by plants.

All model simulations indicated that it would take more than ten years for the wetting front to reach the perched water table. However, this arrival time calculation is highly sensitive to modeling assumptions, including the initial conditions (i.e., starting pressure heads or water contents) and unsaturated hydraulic properties. In addition, there is insufficient site-specific information that can be used to determine the extent of low-permeability zones (or areas of preferential flow), relatively few soil water content measurements near the Arroyo Chico channel, and no measurements of unsaturated hydraulic properties. Therefore, DBS&A stated that the existing models should not be used to predict particle travel times or wetting front arrival times for depths greater than a few meters.

Summary

In summary, based on the infiltration, groundwater, and modeling investigations discussed in this report, the following estimated or calculated ranges were obtained:

- Saturation depths (over a 36-hour period): 22 to 75 feet bgs (based on infiltration assessments performed at the site by Maxim and Montgomery)

- Most infiltration occurred during the first 8 hours of a stormwater flow event (based on predictive groundwater modeling for proposed Basin 1 performed by DBS&A)

- Infiltration rates: 0.18 to 50 feet per day (based on infiltration assessments performed at the site by Montgomery and calculations using off-site data)

- The time for a particle of water to reach the perched aquifer: 10 to 48 days, or up to more than 16 months (based on calculations using off-site data)

- The time for a "piston" response to a rainfall event to be recorded in the perched aquifer: 20 days (based on calculations using off-site data)

- Age of groundwater in the perched aquifer: less than 10 years up to 30 years old (based on calculations from tritium age dating of groundwater at the site performed by SCS and WMCI)

The investigations suggest that construction of the proposed stormwater detention basins will cause increased infiltration of stormwater at the basin locations. Water that is able to infiltrate below the level affected by evapotranspiration could eventually reach the perched aquifer at the site. Because only the near-surface area of the site will be altered by construction, the travel time will be basically the same for both the existing conditions and the proposed basin conditions given the same volume of water entering the system.

Because of the limitations in the data, the actual infiltration rates and depths of infiltration cannot be definitively determined unless additional studies are performed. Because the rates discussed above are considered to be very conservative, it is likely that the actual infiltration rates are much lower than those calculated for this investigation. Although it is unlikely that the proposed basins will infiltrate sufficient water to affect groundwater flow direction and gradient in the perched aquifer beneath the Arroyo Chico site, this determination was beyond the scope of this investigation.

One objective of this investigation was to determine whether the perched aquifer would be impacted by increased infiltration due to the proposed basins. The predictive groundwater modeling found that the proposed stormwater detention basins would cause increased infiltration of stormwater at the basin locations. The modeling simulations also found that a low-permeability liner on the bottom of the basins below the 2-year flood event high water level will reduce infiltration to levels generally equivalent or less than existing conditions. Therefore, installation of an engineered liner would ensure that construction of the basins would not increase infiltration above the existing conditions.

SECTION 11
SUMMARY AND CONCLUSIONS

The COT and County retained SCS to perform a Phase II ESA for the Arroyo Chico Multi-Use Project. The project site encompasses unimproved properties situated in and adjacent to the Arroyo Chico, located between Park Avenue to the west and Kino Parkway to the east. The subject site parcels include unimproved commercial and residential zoned properties. The intended future uses of the project site are multi-use flood control detention basins and public park space. The following discussion summarizes the results of the Phase II ESA investigation.

APARTMENT BUILDINGS

The Arroyo Chico Apartment complex was surveyed for the presence of ACMs and LBP in the event that partial or full demolition of the buildings might be required. Based upon the visual inspection, collection, and analysis of 81 samples for the asbestos survey at the apartments, it was concluded that ACMs are present in the structures on the site. The type of ACM, condition, and locations are discussed below. Repair and/or removal of ACMs should only be performed by qualified individuals utilizing appropriate control methods.

- Drywall texture: Asbestos was detected at a concentration of 2 percent chrysotile asbestos in samples collected from all seven buildings. However, not all texture samples contained asbestos.

- Vinyl floor tile: Asbestos was detected at concentrations of 10 to 15 percent chrysotile asbestos in approximately one-half of the vinyl floor tile samples.

- Vinyl floor tile mastic: Asbestos was detected at a concentration of 2 percent chrysotile asbestos in approximately one-half of the mastic samples.

- Drywall joint compound: Asbestos was detected at a concentration of 2 percent chrysotile asbestos in all but one of the joint compound samples.

- Paper duct tape: Asbestos was detected at concentrations of 50 to 70 percent chrysotile asbestos in all paper duct tape samples.

- Transite (cement asbestos) flues penetrating the roofs and exterior asphaltic roofing materials were assumed to contain asbestos.

A total of 16 paint chip samples were collected from interior, exterior walls, and foundations painted surfaces and analyzed for lead. The following paints contained lead at concentrations that exceeded the laboratory detection limit of 0.003 percent by weight:

- Cream exterior: Lead was detected at concentrations ranging from 0.028 percent to 0.415 percent.

- Brown exterior: Lead was detected at concentrations ranging from below detection limit to 0.351 percent.

- Cream interior on cabinets in Unit 6: Lead was detected at a concentration of 0.011 percent.

- Tan or cream exterior on concrete foundation: Lead was detected at a concentration of 0.007 percent.

These results do not indicate that the overall waste stream that would be generated by demolition of the apartments would be hazardous waste based on the toxicity characteristic for lead.

SHALLOW SOIL ASSESSMENT

Five shallow soil borings (15 feet deep), one deeper soil boring (40 feet deep), nine near surface samples (2 feet deep), and four surface samples were proposed for the project to evaluate locations with the highest probability of contamination, based on existing information. The sample locations were placed in the bottom or sidewalls of the Arroyo Chico or in areas of stained soil and distressed vegetation in order to evaluate areas of reported releases of diesel fuel, tritium, dry cleaning wastes, or other suspect materials. Three of the proposed shallow soil borings were replaced by near surface soil sampling due to inaccessibility to vehicles caused by erosion of caliche beds.

Evidence of staining or odors in cuttings or samples was not observed during drilling of the borings or sample collection. Twenty-nine soil samples were analyzed for VOCs, 26 soil samples were analyzed for semi-VOCs, two soil samples were analyzed for tritium, two soil samples were analyzed for PCBs, and three soil samples were analyzed for geotechnical parameters (bulk density, permeability, porosity, percent moisture, and total organic carbon).

No staining or odors were observed and laboratory results did not identify detectable concentrations of VOCs or semi-VOCs in these samples (or PCBs in the two samples), with the exception of the following. One sample, contained very low concentrations of fluoranthene and pyrene, which are components of diesel fuel. Detected concentrations were over six orders of magnitude less than current ADEQ Residential SRLs.

A concrete vault structure located at 1041 East Miles Street was identified as a potential environmental concern in the project area. A search of COT building records identified the structure as a sand and grease interceptor connected to the public sewer system. The facility at this location was formerly occupied by an automobile washing and detailing business. At the time of the site investigation, the property was occupied by a business that manufactured cast concrete landscaping features. Because the vault was identified as an interceptor that discharges to the sewer system, it is not likely to be the source of significant environmental impact to soils in the Arroyo Chico project area.

INITIAL STORMWATER INFILTRATION ASSESSMENT

A stormwater infiltration assessment (percolation testing) was performed as specified by the COT and County in order to characterize the subsurface profile and determine the potential infiltration characteristics of the subsurface materials at specific locations across the site at the proposed stormwater detention basins. Maxim was retained to perform percolation tests at six locations within the Arroyo Chico project area to evaluate the infiltration characteristics of the subsurface materials beneath the low-permeability caliche layer that is exposed at the base of the arroyo.

Six soil borings were drilled and cased to perform the percolation tests. In an attempt to minimize lateral infiltration effects as much as possible, the borings were lined with large-diameter PVC casings. Constant head and falling head type percolation tests were performed in the test borings. Three different water levels (heads) were used to perform constant head testing within the lined test borings. Water level declines were then measured until the borings were dry or nearly dry.

Percolation rates observed during falling-head tests in the test borings ranged from 4.3 feet per day to 62.0 feet per day, depending on the test location and the amount of hydraulic head (five or ten feet) applied to the test. The slowest percolation rates (4.3 and 9.1 feet per day under 5 and 10 feet of head, respectively) were observed in the test boring closest to the Mission Linen property, which is located across Fremont Avenue from the site. Using very conservative assumptions, Maxim estimated that the potential depth of saturation beneath the proposed basins ranged from 48 to 61 feet bgs for a 36-hour hold time, 32 to 56 feet for a 12-hour hold time, and 13 to 45 feet for a 6-hour hold time. Maxim recommended lining the bottom of the proposed basins if the goal was to prevent infiltration from occurring.

However, infiltration rates over the entire proposed basin area would likely be much less due to factors including (but not limited to) air entrainment, evapotranspiration, siltation, and compaction. In addition, this methodology assumed that nearly all the water percolated in a vertical direction; however, the methodology could not completely eliminate the effects of lateral percolation. Because the methodology did not account for the above factors, the obtained results were assumed to be very conservative.

ADDITIONAL SOILS INVESTIGATION AND STORMWATER INFILTRATION ASSESSMENT

By request of the COT and County, an additional soils investigation and infiltration assessment was performed to clarify the initial infiltration results and to provide additional characterization of the soil profile and the extent of caliche within the channel and proposed basin areas. Montgomery excavated eight infiltration test pits, performed seven double-ring infiltrometer tests and three "small basin" percolation tests within the channel, excavated ten backhoe trenches within the channel, monitored infiltration of ponded water in seven naturally occurring depressions in the well-lithified caliche in the channel, and drilled six soil borings adjacent to the channel.

Stabilized infiltration rates for the infiltrometer tests ranged from 1.4 to 2 feet per day in three of the test pits and from 17 to 39 feet per day in four of the test pits. The lower infiltration rates were interpreted by Montgomery to be due to weak to moderate lithification of the sediments. The small basin tests obtained infiltration rates of 3 to 5 feet per day. Significant lateral migration was observed at one of the test pits, with a saturated depth in soils beneath the test area of only 3 to 4 inches following the testing. Infiltration rates measured at the naturally occurring depressions in the lithified caliche in the channel ranged from 0.04 to 0.4 feet per day.

Montgomery estimated that the representative average infiltration capacity for the Arroyo Chico site would be between 3 to 10 feet per day. Depending on the continuity of moderately-to well-lithified sediments, the infiltration could be less than 3 feet per day or more than 10 feet per day. Dividing this average infiltration capacity by a fillable porosity of 20 percent, the projected depth of wetting front movement would be 15 to 50 feet per day, or 22 to 75 feet for the maximum 36-hour detention time for the stormwater. Montgomery recommended lining the bottom of the proposed basins to ensure that significant infiltration would not occur.

Limitations identified for the use of this data included the small scale of the tests versus the size of the proposed basins, the observation of lateral flow during some of the infiltration tests, and lack of information regarding the continuity of moderately- to well-lithified sediments beneath the basins. The tests assumed a maximum predicted depth of water for a full 36 hours, whereas most storm events would result in smaller volumes of water stored in the proposed basins over shorter periods of time. The testing also did not account for repeated basin-filling events. In addition, it is likely that fine-grained sediments and organic materials would settle out of stormwater and accumulate on the basin floors after several filling cycles. Infiltration capacity could be greatly reduced due to the accumulation of this surface "skin."

INITIAL GROUNDWATER ASSESSMENT

Two pairs of nested groundwater monitoring wells (WR-345 and WR-347) were installed on COT property at locations reviewed by ADEQ to evaluate groundwater quality concerns associated with the Park-Euclid WQARF site, groundwater gradient, and flow direction beneath the proposed basins. The proposed detention basins include three separate basins situated generally along the axis of the Arroyo Chico wash, with the western basin (referred to as Basin 1) located across the street from the Mission Linen property.

Each nested well location contains a pair of wells completed at two intervals to evaluate the perched aquifer (depth to groundwater generally 96 feet bgs) and the regional aquifer (depth to groundwater generally 200 feet bgs). One of these well locations (WR-347) was placed at the western edge of the proposed western Basin 1 (between Mission Linen and the basin) and the other well location (WR-345) was placed on the opposite (northeast) side of Basin 1.

One groundwater sampling event was performed for the nested wells in February 1998. This sampling event detected PCE, naphthalene, and bis (2-ethylhexyl) phthalate. PCE and naphthalene are likely associated with the solvent and diesel fuel impacts that have been detected at Mission Linen, but phthalates are typically related to plastic compounds and may be associated with drilling or sampling procedures.

Laboratory analytical results indicated that the perched aquifer well at the western edge of the proposed Basin 1 (across the street from the Mission Linen property) contained PCE at a concentration of 34 μg/L, which exceeds the AWQS of 5 μg/L. This well also contained naphthalene and bis (2-ethylhexyl) phthalate at low concentrations. The perched aquifer well northeast of the proposed Basin 1 did not contain PCE, but it did contain phthalate at lower concentrations. The regional aquifer well at the western edge of the proposed Basin 1 contained a very low concentration of phthalate, and the regional aquifer well northeast of the basin contained low concentrations of PCE (2.9 μg/L, which is below the AWQS).

Seven soil samples were collected during drilling of the well borings; these samples were collected at depths ranging from 70 to 110 feet bgs. Laboratory analysis of these soil samples did not identify the presence of analytes exceeding laboratory reporting limits.

Based on groundwater level measurements collected from the Arroyo Chico and Mission Linen monitoring wells in 1998, the direction of groundwater flow in both the perched and regional aquifers was to the northeast. The groundwater gradient was variable across the project area, but averaged approximately 0.006 feet per foot.

RISK ASSESSMENT

Based on the results of the shallow soil assessment, soil contamination was not identified on the Arroyo Chico site; so risks associated with soil contamination are not anticipated. Groundwater collected from the site wells contained detectable concentrations of PCE, naphthalene, and bis (2-ethylhexyl) phthalate. The concentration of PCE exceeded the drinking water quality standard. However, because there are no on-site drinking water wells or other potential pathways by which persons on the site could be exposed to contaminated groundwater, groundwater contamination detected beneath the site should not present health risks to persons occupying the site. However, if groundwater contamination were to continue to migrate from the Arroyo Chico monitoring well locations to off-site drinking water wells, an exposure pathway could be completed, and health risks could exist for those obtaining drinking water from the wells.

A preliminary, screening-level groundwater modeling risk assessment was performed for the site. This risk assessment indicated that the possibility exists for groundwater contamination detected at the Arroyo Chico and Mission Linen monitoring wells to potentially impact potable water wells to the north. This assessment was based on very conservative assumptions, and therefore overestimates the likelihood that contamination may reach these wells. Due to the preliminary nature of this modeling effort, potential health effects at these potable water wells were not evaluated.

ADDITIONAL GROUNDWATER ASSESSMENTS

Based on the results of the two stormwater infiltration assessments, the COT and County requested additional investigation of groundwater characteristics to provide more information on the potential for infiltration of stormwater at the site. Tasks included sampling and analysis of groundwater for VOCs, sampling and analysis of groundwater and surface water to perform tritium age-dating, installation and continuous logging of groundwater levels using electronic water level indicators (transducers) in both the perched and regional aquifers, collection of information for predictive modeling, and preparation of technical memoranda documenting the investigations.

Groundwater Sampling and Analysis

Groundwater samples were collected and analyzed from the perched and regional aquifer wells located at WR-347. PCE (160 µg/L), acenaphthene (9.1 µg/L), and bis (2-ethylhexyl) phthalate (45 µg/L) were detected in the groundwater sample from the perched aquifer well (WR-347A) and bis (2-ethylhexyl) phthalate (7.7 µg/L) was detected in the groundwater sample from the regional aquifer well (WR-347B). The concentration of PCE detected in the sample from the perched aquifer well exceeded the AWQS of 5 µg/L. No AWQS for acenaphthene and bis (2-ethylhexyl) phthalate have been established. The Park-Euclid WQARF site is the likely source of the contaminants detected in groundwater samples collected from the subject site wells.

Tritium Age Dating

Tritium age dating was performed for one surface water sample from the Arroyo Chico and groundwater samples from wells WR-347A and WR-347B. The laboratory analytical results were 12.6 Tritium Units (TU) for the sample from WR-347A, 0.05 TU (below the laboratory detection limit of 0.1 TU) for the sample from WR-347B, and 4.12 TU for the surface water sample. The results of the tritium age-dating of the perched aquifer, regional aquifer, and surface water at the project site indicate that the regional aquifer contains groundwater that is at least 50 years old, groundwater in the perched aquifer exhibits an average age of at least 10 years (and less than 30 years), and the two aquifer systems are not in hydraulic communication. Releases of tritium from a facility in the site area during the 1970s could cause the actual age of the perched groundwater to be less than the calculated minimum age of 10 years.

Monitoring of Groundwater Levels

Continuous monitoring of groundwater elevations in perched aquifer well WR-347A and regional aquifer well WR-347B was performed using electronic water level indicators (transducers) from December 10, 1999 through July 28, 2000 at 15-minute intervals. Cyclical fluctuations and a general downward trend were recorded for the water elevations of both the perched and regional aquifer wells. An apparent groundwater recharge event was recorded on January 12, 2000 for the perched aquifer well; no other indications of groundwater recharge were recorded for the well. The groundwater elevations in the regional aquifer did not appear to exhibit any response to the apparent recharge events observed in the perched aquifer data.

Because of unknown factors, such as vadose zone antecedent moisture conditions, the area receiving rainfall, and the effects of local lithology on channeling groundwater flow, it is difficult to correlate one rainfall event with a change in water level using this limited data set. Thus, the rate at which precipitation is recharging the aquifer cannot be determined based on the hydrograph data.

Collection and Interpretation of Supporting Data

The Arroyo Chico flows generally west-northwest towards the Santa Cruz River. Two saturated groundwater zones have been identified in the vicinity of the site: a perched aquifer at approximately 96 feet below land surface, and the semi-confined to confined regional aquifer at approximately 200 feet below land surface. The perched aquifer extends south and west of the site, but apparently pinches out less than a mile north of the site. The areal extent and configuration of the pinch-out zone would be expected to control groundwater flow direction, as well as the capacity of the aquifer to maintain a head of water above the aquitard. Groundwater flow in both the perched and regional aquifers in the vicinity of the site is to the northeast. The regional aquifer provides water supply to the City of Tucson, and heavy withdrawal from the UA water supply well field north of the site is believed to influence the direction of regional groundwater flow in the site area.

Rainfall and Barometric Pressure Data

Rainfall and barometric pressure data for the Arroyo Chico area, recorded at a weather station located at the UA approximately 0.75 mile directly north of the Arroyo Chico project site, was obtained for the period of investigation. The water level data collected by the transducers placed in the site wells were corrected for the effects of barometric pressure and diurnal fluctuations; the correction for barometric pressure did not fully explain the magnitude of the variations in the water levels. Because the period of hydrograph data was limited, it was difficult to discern a relationship between a specific rainfall event and a groundwater recharge response. However, recharge apparently occurred in the perched aquifer from September 1999 through January 2000, including the January 12 recharge event. It is probable that the rise in the groundwater elevation represents recharge to the perched aquifer by drainage of water from the Arroyo Chico channel.

Other Tucson Area Studies

Other Tucson area studies have reported wetting front migration velocities of 1.9 to 9.0 feet per day for recharge zones similar to the perched aquifer at the site. Isotope studies of recharge in the Rillito River have measured an approximate 2-year travel time through the vadose zone at a rate of approximately 0.18 feet per day. However, hydrograph responses to individual rainfall events were reflected approximately 30 days after a substantial rainfall, possibly attributed to a “piston” pressure flow response, which causes infiltrated water to push downward on water already present in the vadose zone, thus inducing a recharge response at the water table.

Comparison of Site Investigation Data With Other Tucson Area Data

If it is assumed that the approximately 90 feet of vadose zone beneath the Arroyo Chico channel is similar to that beneath the Rillito River channel area, a particle of water could take a minimum of approximately 16 months to reach the water table. However, the “piston” pressure flow response could induce a recharge response in the groundwater levels in as little as 20 days. Using the measured wetting front velocities of 1.9 to 9.0 feet per day observed for other studies performed in the Tucson area, the estimated time for the observed hydrograph response to a recharge event at the site would be within 10 to approximately 48 days.

Comparing these estimated times of travel to rainfall events recorded at the UA weather station, there should have been responses evident on the hydrograph for WR-347A sometime between mid January and early August. No hydrograph responses were identified during the monitoring period. If the general rise in groundwater elevations observed between September 1999 and January 2000 represents a series of discrete "piston" recharge events following the 1999 monsoon season, the January 12, 2000 rise might represent the end of recharge attributable to the monsoon rainfall.

PREDICTIVE GROUNDWATER MODELING

By request of the COT and County, SCS retained DBS&A to perform predictive groundwater modeling to evaluate the effect of infiltration of stormwater at the locations of the proposed stormwater detention Basin 1. The objectives were to estimate the difference in infiltration for scenarios without the proposed basin (existing conditions) and with the proposed basin (after construction). Tasks performed included compilation and analysis of existing data, development of a conceptual hydrologic model based on the existing data, construction of numerical models, and performance of simulations to quantify potential infiltration.

Information used to establish the hydrogeologic setting for the site area was obtained by reviewing data collected by SCS, Maxim, and Montgomery during the previous work performed for this project investigation and by review of documents at ADEQ for investigations of the Park-Euclid WQARF site. The computer modeling used the computer code HYDRUS-2D, which uses a finite element approach to solve the Richards equation for water flow in variably saturated media, and allows for transient variations in boundary conditions. The modeling profiles were based on an average (or representative) cross section of Basin 1, and boundary conditions used for the simulations included no-flow, variable pressure head (to simulate ponding), and prescribed pressure head boundaries; the lower boundary was the top of the perched aquifer. Hydraulic parameters required for the model input included residual and saturated water contents, saturated hydraulic conductivity, and fitting parameters for the soil-water retention and unsaturated hydraulic conductivity functions, which were derived using the analytical model of van Genuchten. Because there was little to no site-specific data available for the above parameters, these values had to be estimated.

Three separate surface water flow events were simulated for each of the two model scenarios: the 100-year, 10-year, and 2-year flow events. Ponded infiltration into the subsurface soils was simulated during the period of saturated conditions. Each simulation was run for a period of 50 years. Additional simulations were performed to evaluate the sensitivity of the model results to variations in the initial conditions.

The simulations showed that infiltration is consistently greater for the scenarios with the basin in place than for the existing conditions at ratios ranging from 2.8:1 to 3.0:1. Both the basin and existing conditions scenarios show that most of the infiltration occurs in the first 8 hours of each flow event. The scenarios that simulated usage of a low hydraulic conductivity material on the basin floor showed that partially lining the basin could significantly limit infiltration to amounts less than or generally equivalent to the existing infiltration amounts.

DBS&A explicitly stated that the simulations should not be used to estimate wetting front migration rates or vadose zone travel times for depths greater than a few meters, because this arrival time calculation is highly sensitive to modeling assumptions, including the initial conditions (i.e., starting pressure heads or water contents) and unsaturated hydraulic properties, as well as lithologic heterogeneity of the subsurface soils (such as clay lenses). There was insufficient site-specific information that could be used to determine the extent of low-permeability zones (or areas of preferential flow), relatively few soil water content measurements near the Arroyo Chico channel, and no measurements of unsaturated hydraulic properties. Because only the near-surface area will be altered by construction, the travel time will be basically the same for both scenarios given the same volume of water entering the system. According to DBS&A, it was impossible to accurately quantify the overall influence of vegetation on the water balance for the project scenarios because there are no soil parameter data for vegetated areas. Vegetated soils generally have permeabilities an order of magnitude higher than non-vegetated soils due to macropores and other soil structures created by plants.

DISCUSSION OF STORMWATER INFILTRATION, GROUNDWATER ASSESSMENT, AND GROUNDWATER MODELING RESULTS

The results from the infiltration and groundwater modeling investigations discussed in this report are limited by the paucity of site-specific soil and groundwater information, including (but not limited to) the extent of moderately- to well-lithified sediments, soil moisture contents, lithologic heterogeneity, unsaturated hydraulic properties, locations of preferential flow pathlines, and long-term groundwater levels. Actual stormwater infiltration rates over the entire basin area would likely be much less than was calculated due to factors including (but not limited to) air entrainment, evapotranspiration, siltation, and compaction. The collection of additional data would require extensive additional soil and groundwater investigations. Without additional data, the results discussed in this report must be viewed as conservative estimates based on the limited available data.

Limitations for the investigations included the small scale of the infiltration tests versus that of the proposed basins; the very wide range of results for the infiltration rates obtained during the testing (nearly 0 feet per day up to 40 feet per day), which made development of a reasonable average infiltration rate or even a range of rates difficult; lateral flow during infiltration testing, which results in an overestimate of the steady-state infiltration rate; the lack of information regarding the continuity and extent of moderately- to well-lithified sediments and the degree of heterogeneity of sediments beneath the basins; the effect of siltation on the bottom of the basins, which would limit infiltration of stormwater; and assumptions used for the infiltration tests that included a constant maximum depth of water for the full 36-hour period, a single basin-filling event, and saturated conditions. Groundwater modeling is a predictive tool that can only simulate conditions based on input values that are chosen to best represent site conditions. The results for the groundwater modeling simulations are entirely dependent upon the values used for the model input; if there is little site-specific information available, the input values must be estimated, which can result in simulations that may or may not represent actual site conditions.

If the project goal is to keep the net infiltration of water the same for the constructed basins as for the existing site conditions, Maxim, Montgomery, and DBS&A recommended that the bottom of the basins be lined. DBS&A recommends that the basins be lined to the high water level of the 2-year flood event with a reduced permeability material consisting of compacted soil, soil amendments, or synthetic material. The area requiring reduced permeability can also be minimized by altering the footprint of the 2-year flood event using berms or terraces.

GLOSSARY OF ACRONYMS AND ABBREVIATIONS

ACM	Asbestos-containing material
ADEQ	Arizona Department of Environmental Quality
ADHS	Arizona Department of Health Services
ADWR	Arizona Department of Water Resources
AGRA	AGRA Earth and Environmental Inc.
AHERA	Asbestos Hazard Emergency Response Act
AWQS	Aquifer Water Quality Standard
AT123D	Analytical, Transient, 1-, 2-, or 3-Dimensional Model
ATEL	Aqua Tech Environmental Laboratories, Inc.
B_E	Barometric efficiencies
bgs	Below ground surface
cm/sec	Centimeters per second
COT	City of Tucson
County	Pima County
CTI	Chemical Transportation, Inc.
DBS&A	Daniel B. Stephens & Associates
DCE	Dichloroethene
EIS	Environmental Impact Study
EMC	EMC Laboratories
EPA	Environmental Protection Agency
ERI	Environmental Response, Inc.
ESA	Environmental Site Assessment
gpm	Gallons per minute
GSI	Geomechanics Southwest Inc.
HRA	Human Health Risk Assessment
IDW	Investigative-derived waste
LADPW	Los Angeles Department of Public Works
Layne	Layne Christensen Company
LBP	Lead-based paint
lbs/cf	Pounds per cubic foot
Maxim	Maxim Technologies, Inc.
MDA	Minimum detectable activity
mg/kg	Milligrams per kilogram
mg/L	Milligrams per liter
Mission Linen	Mission Uniform & Linen Service
Montgomery	Errol L. Montgomery & Associates
msl	Mean sea level
NESHAP	National Emission Standards for Hazardous Air Pollutants
NOI	Notice of Intent (ADWR drilling permit application)
NVLAP	National Voluntary Laboratory Accreditation Program
PCBs	Polychlorinated biphenyls
PCE	Tetrachloroethene
pCi/g	PicoCuries per gram
PCWW	Pima County Waste Water

P.G.	Professional Geologist
PLM	Polarized light microscopy
ppb	Parts per billion
R.G.	Registered Geologist
SCS	SCS Engineers
SRL	Soil Remediation Level
TCA	Trichloroethane
TCE	Trichloroethene
TGI	Transwest Geochem, Inc.
TOC	Total organic carbon
TPH	Total Petroleum Hydrocarbons
TU	Tritium Units
Turner	Turner Laboratories Inc.
UA	University of Arizona
μg/kg	Micrograms per kilogram
μg/L	Micrograms per liter
USACE	United States Army Corps of Engineers
USGS	United States Geological Survey
VOA	Volatile organic analyte
VOC	Volatile organic compound
WMCI	Water Management Consultants, Inc.
WQARF	Water Quality Assurance Revolving Fund (State Superfund)

FIGURES

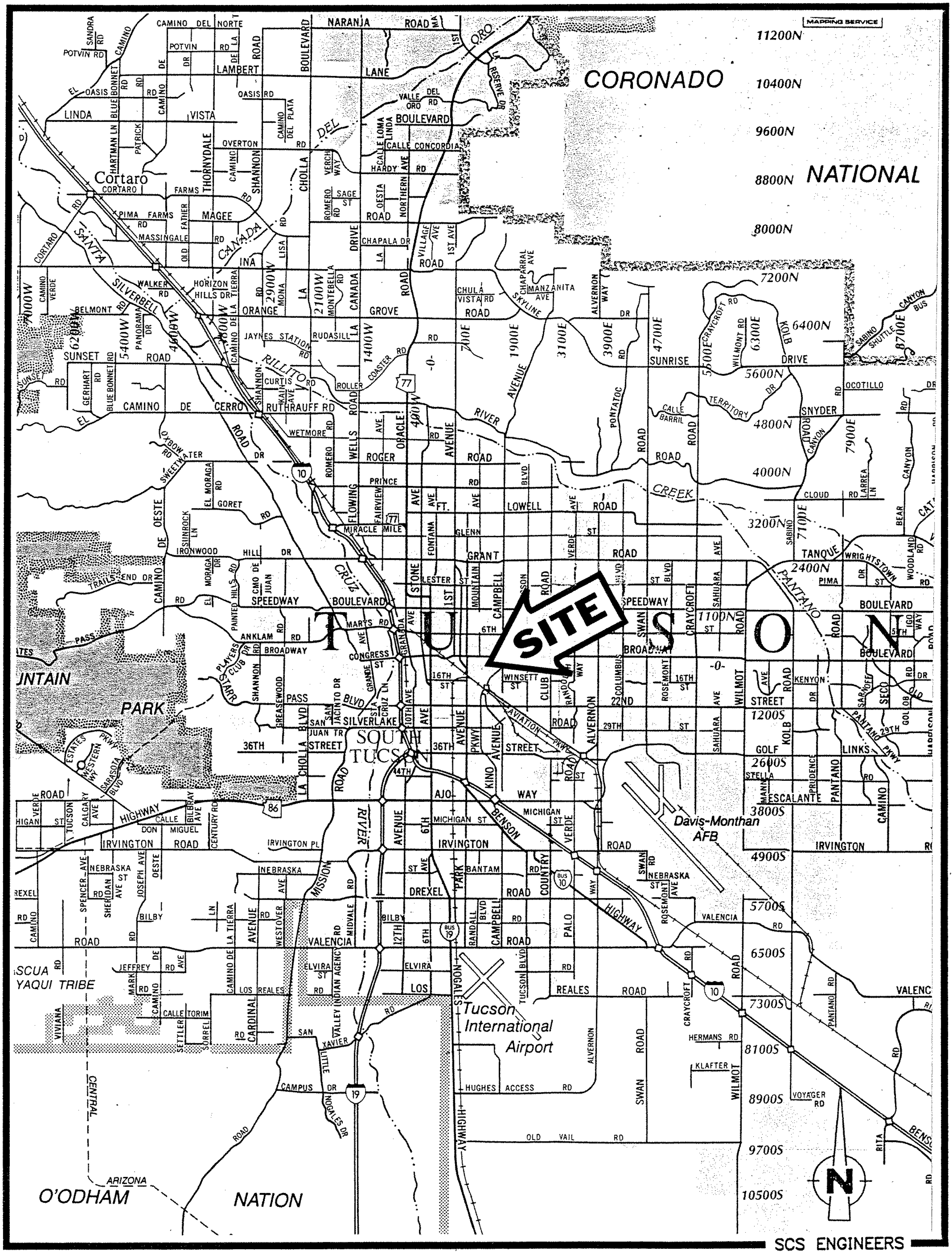
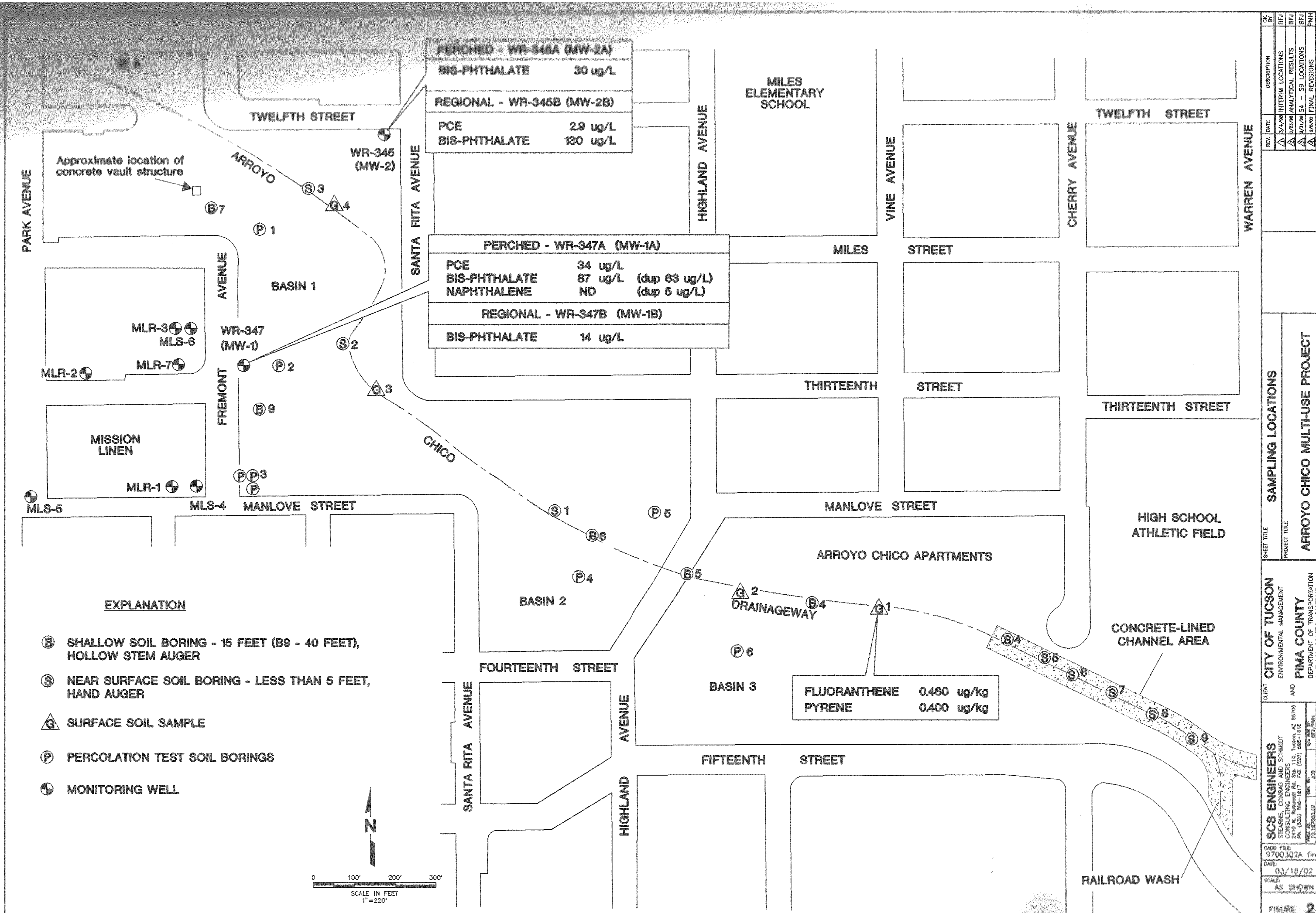


FIGURE 1. SITE LOCATION MAP



PERCHED - WR-345A (MW-2A)
BIS-PHTHALATE 30 ug/L
REGIONAL - WR-345B (MW-2B)
PCE 2.9 ug/L
BIS-PHTHALATE 130 ug/L
WR-345 (MW-2)
PERCHED - WR-347A (MW-1A)
PCE 34 ug/L
BIS-PHTHALATE 87 ug/L (dup 63 ug/L)
NAPHTHALENE ND (dup 5 ug/L)
REGIONAL - WR-347B (MW-1B)
BIS-PHTHALATE 14 ug/L
WR-347 (MW-1)
FLUORANTHENE 0.460 ug/kg
PYRENE 0.400 ug/kg
Approximate location of concrete vault structure
TWELFTH STREET
MILES ELEMENTARY SCHOOL
MILES STREET
THIRTEENTH STREET
MANLOVE STREET
FOURTEENTH STREET
FIFTEENTH STREET
PARK AVENUE
FREMONT AVENUE
SANTA RITA AVENUE
HIGHLAND AVENUE
VINE AVENUE
CHERRY AVENUE
WARREN AVENUE
ARROYO CHICO DRAINAGEWAY
BASIN 1
BASIN 2
BASIN 3
MISSION LINEN
ARROYO CHICO APARTMENTS
HIGH SCHOOL ATHLETIC FIELD
CONCRETE-LINED CHANNEL AREA
RAILROAD WASH
MLR-1
MLR-2
MLR-3
MLR-7
MLS-4
MLS-5
MLS-6
EXPLANATION
SHALLOW SOIL BORING - 15 FEET (B9 - 40 FEET), HOLLOW STEM AUGER
NEAR SURFACE SOIL BORING - LESS THAN 5 FEET, HAND AUGER
SURFACE SOIL SAMPLE
PERCOLATION TEST SOIL BORINGS
MONITORING WELL
N
0 100' 200' 300'
SCALE IN FEET 1"=220'
REV. DATE DESCRIPTION CK. BY
3/4/98 INTERIM LOCATIONS BFJ
3/23/98 ANALYTICAL RESULTS BFJ
3/31/98 S4 - S9 LOCATIONS BFJ
2/8/02 FINAL REVISIONS PMH
3/18/02 FINAL REVISIONS PMH
SHEET TITLE SAMPLING LOCATIONS
PROJECT TITLE ARROYO CHICO MULTI-USE PROJECT
CLIENT CITY OF TUCSON ENVIRONMENTAL MANAGEMENT
AND PIMA COUNTY DEPARTMENT OF TRANSPORTATION & FLOOD CONTROL DISTRICT
SCS ENGINEERS
STEARNS, CONRAD AND SCHMIDT CONSULTING ENGINEERS
CADD FILE: 9700302A final
DATE: 03/18/02
SCALE: AS SHOWN
FIGURE 2

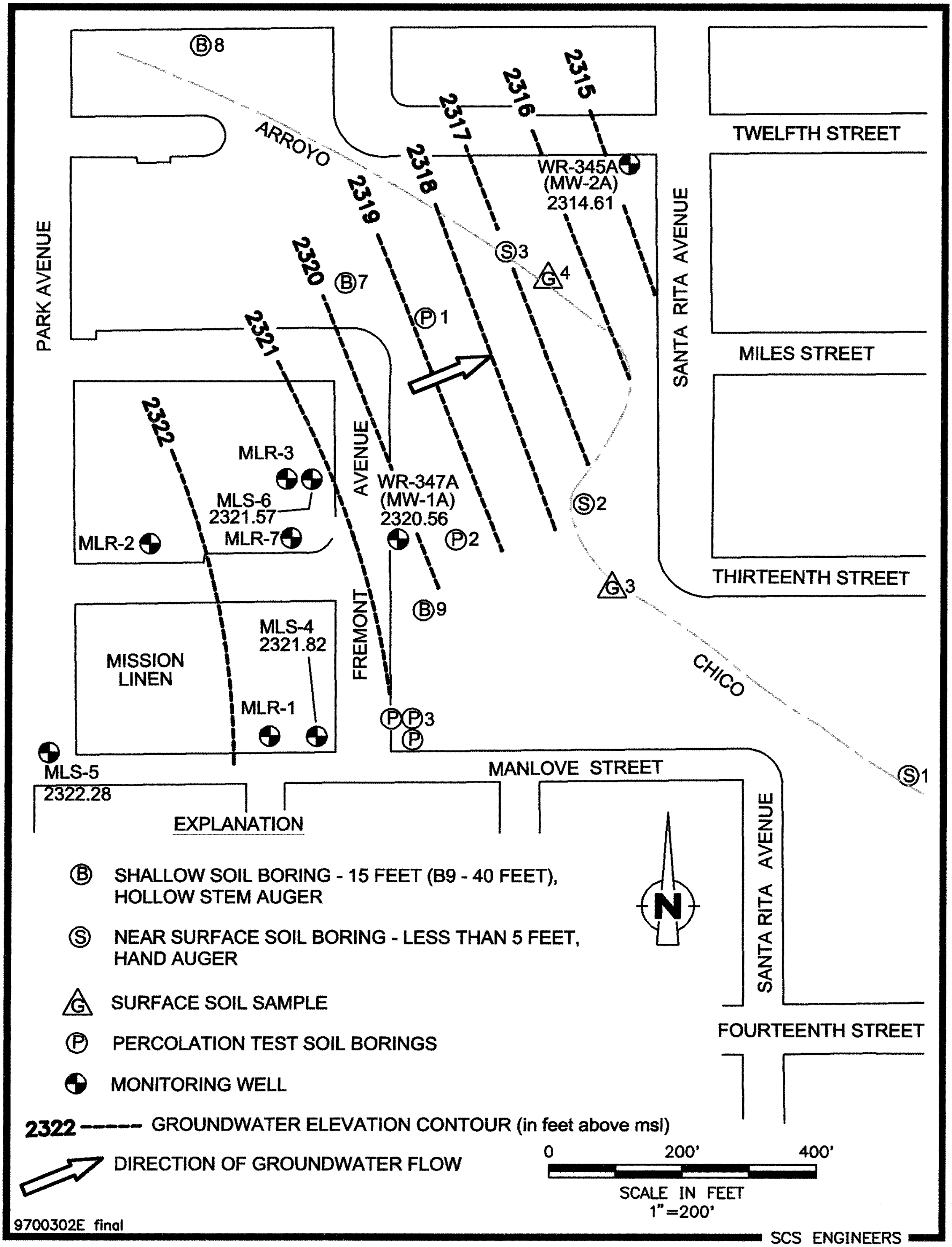


FIGURE 3A. GROUNDWATER CONDITIONS MAP
PERCHED AQUIFER – FEBRUARY 25, 1998

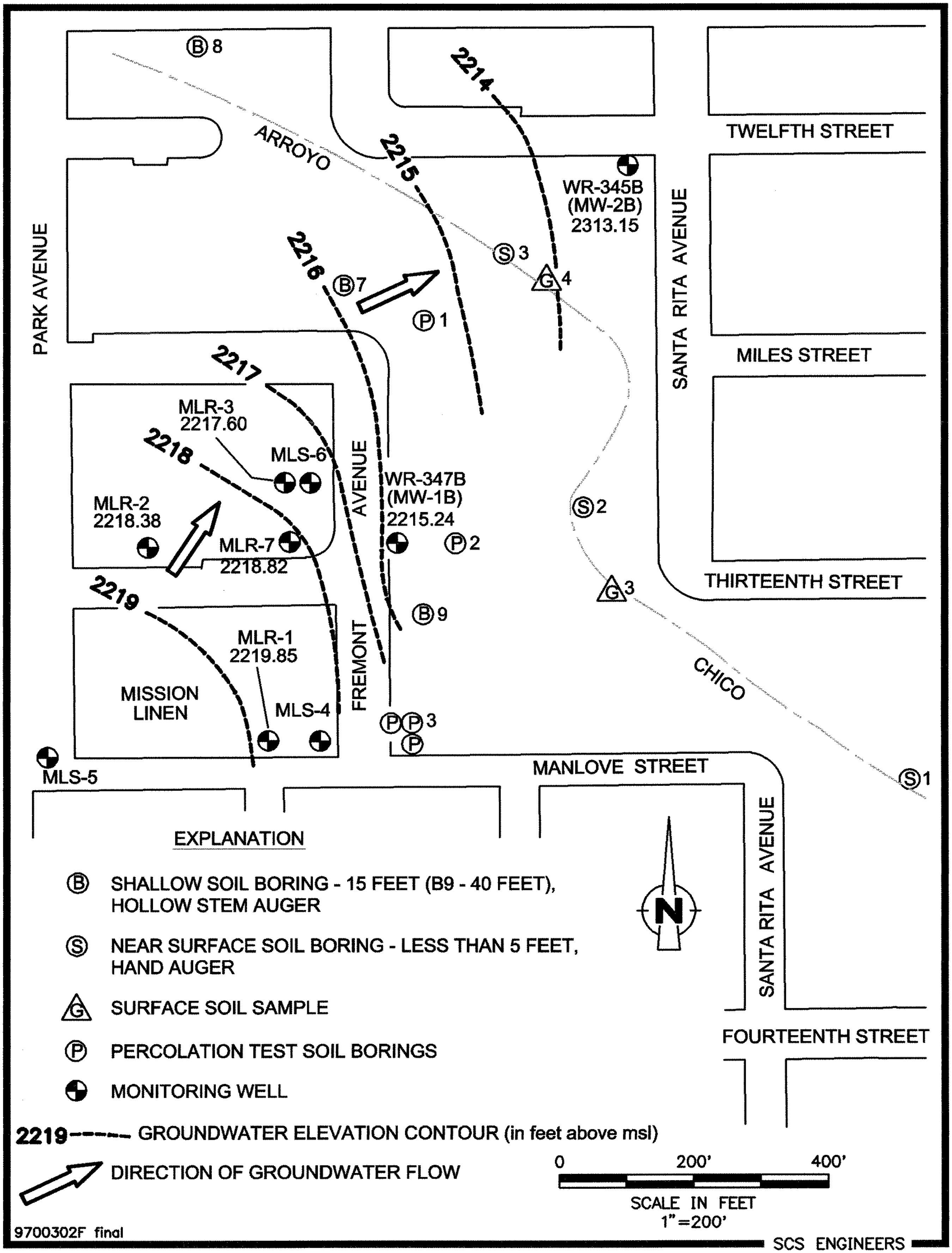


FIGURE 3B. GROUNDWATER CONDITIONS MAP
REGIONAL AQUIFER – MARCH 20, 1998

TABLES

TABLE 1. SUMMARY OF ENVIRONMENTAL SAMPLE ANALYSES AND RESULTS - ARROYO CHICO PROJECT

Sample ID	Sample Date	Matrix	Analyses	Date Extracted	Date Analyzed	Results
SURFACE SAMPLES						
G1-S	1/30/98	Soil	8260, 8270, Tritium	1/31/98, 2/5/98, NI	2/1/98, 2/11/98, 2/5/98	ND, *, *
G2-S	1/30/98	Soil	8260, 8270, Tritium	1/31/98, 2/5/98, NI	2/1/98, 2/10/98, 2/5/98	ND, ND, *
G3-S	1/30/98	Soil	8260, 8270	1/31/98, 2/5/98	2/1/98, 2/11/98	ND, ND
G-4	1/28/98	Soil	8260, 8270	1/30/98, 2/3/98	1/30/98, 2/5/98	ND, ND
NEAR SURFACE SAMPLES						
S1-2	1/30/98	Soil	8260, 8270	1/31/98, 2/5/98	2/1/98, 2/11/98	ND, ND
S2-2	1/30/98	Soil	8260, 8270	1/31/98, 2/5/98	2/1/98, 2/11/98	ND, ND
S3-2	1/28/98	Soil	8260, 8270	1/30/98, 2/3/98	1/30/98, 2/6/98	ND, ND
S4-2	3/17/98	Soil	8260, 8270	3/18/98, 3/25/98	3/18/98, 4/1/98	ND, ND
S5-2	3/17/98	Soil	8260, 8270	3/18/98, 3/25/98	3/18/98, 4/1/98	ND, ND
S6-2	3/17/98	Soil	8260, 8270	3/18/98, 3/25/98	3/18/98, 4/1/98	ND, ND
S7-0.5	3/18/98	Soil	8260, 8270	3/19/98, 4/3/98	3/19/98, 4/7/98	ND, ND
S8-1	3/18/98	Soil	8260, 8270	3/19/98, 3/25/98	3/19/98, 4/1/98	ND, ND
S9-1	3/18/98	Soil	8260, 8270	3/19/98, 3/25/98	3/19/98, 4/1/98	ND, ND
SHALLOW SOIL BORING SAMPLES						
B4-2	1/29/98	Soil	8260, 8270	1/30/98, 2/3/98	1/31/98, 2/6/98	ND, ND
B4-14.5	1/29/98	Soil	8260, 8270	1/30/98, 2/3/98	1/31/98, 2/6/98	ND, ND
B5-2	1/29/98	Soil	8260, 8270	1/30/98, 2/3/98	1/31/98, 2/6/98	ND, ND
B5-15	1/29/98	Soil	8260, 8270	1/30/98, 2/3/98	1/31/98, 2/6/98	ND, ND
B6-2	1/29/98	Soil	8260, 8270	1/30/98, 2/3/98	1/31/98, 2/6/98	ND, ND
B6-15	1/29/98	Soil	8260, 8270	1/30/98, 2/3/98	1/31/98, 2/6/98	ND, ND
B7-2	1/28/98	Soil	8260, 8270	1/30/98, 2/3/98	1/30/98, 2/6/98	ND, ND
B7-15	1/28/98	Soil	8260, 8270	1/30/98, 2/3/98	1/30/98, 2/6/98	ND, ND
B8-2	1/28/98	Soil	8260, 8270, PCBs	1/30/98, 2/3/98, 2/4/98	1/30/98, 2/6/98, 2/6/98	ND, ND, ND
B8-15	1/28/98	Soil	8260, 8270, PCBs	1/30/98, 2/3/98, 2/4/98	1/30/98, 2/6/98, 2/6/98	ND, ND, ND
B9-2	1/29/98	Soil	8260, 8270	1/30/98, 2/3/98	1/31/98, 2/6/98	ND, ND
B9-8	1/29/98	Soil	8260	1/30/98	1/31/98	ND
B9-15	1/29/98	Soil	8260, 8270	1/30/98, 2/3/98	1/31/98, 2/6/98	ND, ND
B9-22	1/29/98	Soil	8260	1/30/98	1/31/98	ND
B9-30	1/29/98	Soil	8260	1/30/98	1/31/98	ND
B9-40	1/29/98	Soil	8260, 8270	1/30/98, 2/3/98	1/31/98, 2/6/98	ND, ND
MONITORING WELL BORING SOIL SAMPLES						
MW1-80	2/2/98	Soil	8260, 8270	2/4/98, 2/9/98	2/4/98, 2/11/98	ND, ND
MW1-90	2/2/98	Soil	8260, 8270	2/4/98, 2/9/98	2/4/98, 2/11/98	ND, ND

TABLE 1. SUMMARY OF ENVIRONMENTAL SAMPLE ANALYSES AND RESULTS - ARROYO CHICO PROJECT

Sample ID	Sample Date	Matrix	Analyses	Date Extracted	Date Analyzed	Results
MW1-100	2/2/98	Soil	8260, 8270	2/4/98, 2/9/98	2/4/98, 2/11/98	ND, ND
MW1-110	2/2/98	Soil	8260, 8270	2/4/98, 2/9/98	2/4/98, 2/11/98	ND, ND
MW2-70	1/26/98	Soil	8260, 8270	1/28/98, 1/30/98	1/30/98, 2/2/98	ND, ND
MW2-90	1/27/98	Soil	8260, 8270	1/28/98, 1/30/98	1/30/98, 2/2/98	ND, ND
MW2-100	1/27/98	Soil	8260, 8270	1/28/98, 1/30/98	1/30/98, 2/2/98	ND, ND
INVESTIGATIVE-DERIVED WASTES						
MW1-IDW	2/6/98	Wastewater	624	NI	2/16/98	ND
MW1-IDW2	2/10/98	Wastewater	624	NI	2/16/98	*
MW1-IDW	2/11/98	Soil	8260, 8270, 418.1	2/11/98, 2/12/98, NI	2/13/98, 2/13/98, 2/12/98	ND, *, *
MW2-IDW	1/30/98	Wastewater	624	NI	2/4/98	ND
MW2-IDW	2/2/98	Soil	8260, 8270, 418.1	2/4/98, 2/9/98, NI	2/4/98, 2/11/98, 2/8/98	ND, ND, *
MONITORING WELL GROUNDWATER SAMPLES						
MW-1A	2/23/98	Groundwater	624, 625	NI, NI	2/26/98, 3/11/98	*, *
DUP	2/23/98	(MW-1A)	625	NI	3/11/98	*
MW-1B	2/23/98	Groundwater	624, 625	NI, NI	2/26/98, 3/11/98	ND, *
DUP	2/23/98	(MW-1B)	624	NI	2/26/98	ND
MW-2A	2/23/98	Groundwater	624, 625	NI, NI	2/26/98, 3/11/98	ND, *
MW-2B	2/23/98	Groundwater	624, 625	NI, NI	2/26/98, 3/11/98	*, *

NOTES:

NI = Not identified
ND = Not detected above laboratory method detection limits (full laboratory reports provided in Appendices E and K)
* = Detected above laboratory method detection limits, See Table 2

EXPLANATION OF SAMPLE IDENTIFIERS:

G1-S = Grab soil sample number 1, collected from surface soil (0 to 6 inches deep)
S1-2 = Near surface soil probe/hand auger sample number 1, collected from 0-2 feet below ground surface (bgs)
B6-15 = Soil boring number 6, soil sample collected from 15 feet bgs
MW1-90 = Monitoring well location WR-347, soil sample collected from 90 feet bgs
MW2-IDW = Monitoring well location WR-345, Investigative-Derived Waste sample
MW-1A and MW-2A = Perched (shallow) monitoring well, locations WR-347A and WR-345A, respectively
MW-1B and MW-2B = Regional (deep) monitoring well, locations WR-347B and WR-345B, respectively

TABLE 2. DETECTED COMPOUNDS – ARROYO CHICO PROJECT

Sample ID	Analysis	Parameter	Results		Regulatory Limits	
SOIL SAMPLES						
G1-S	8270	Fluoranthene	0.460	μg/kg	2,600,000	μg/kg[A]
	8270	Pyrene	0.400	μg/kg	2,000,000	μg/kg[A]
	906	Tritium	0.02 ± 0.03	pCi/g		
G2-S	906	Tritium	-0.01 ± 0.04	pCi/g		
WASTE SOIL SAMPLES						
MW1-IDW	8270	Bis (2-ethylhexyl) phthalate	1,200	μg/kg		
	418.1AZ	TRPH	64	mg/kg		
MW2-IDW	418.1AZ	TRPH	29	mg/kg		
WASTEWATER SAMPLES						
MW1-IDW2	624	Tetrachloroethene	3.6	μg/L	700	μg/L[B]
GROUNDWATER SAMPLES						
MW-1A	624	Tetrachloroethene	34	μg/L	5	μg/L[C]
	625	Bis (2-ethylhexyl) phthalate	87	μg/L		
	625 (duplicate)	Bis (2-ethylhexyl) phthalate	63	μg/L		
		Naphthalene	5	μg/L		
MW-1B	625	Bis (2-ethylhexyl) phthalate	14	μg/L		
MW-2A	625	Bis (2-ethylhexyl) phthalate	30	μg/L		
MW-2B	624	Tetrachloroethene	2.9	μg/L	5	μg/L[C]
	625	Bis (2-ethylhexyl) phthalate	130	μg/L		

NOTE: MW-1 is the former name of well location WR-347 and MW-2 is the former name of well location WR-345
TRPH = Total Recoverable Petroleum Hydrocarbons

REGULATORY LIMITS:

[A] Arizona Department of Environmental Quality Residential Soil Remediation Levels (SRLs) (effective date December 4, 1997)

[B] Environmental Protection Agency (EPA) Maximum Concentration of Contaminants for the Toxicity Characteristic (40 CFR 261.24)

[C] Arizona Numeric Aquifer Water Quality Standards (AWQS): Drinking Water Protected Use (AAC Title 18, Ch. 11, Supp. 95-3) and EPA Maximum Contaminant Levels (MCLs) for Organic Contaminants (40 CFR 141.61)

TABLE 3. WATER LEVEL MEASUREMENTS – ARROYO CHICO PROJECT

Well ID	Date	Time	Depth to Water[A]	Odor?	Product Thickness[B]	Datum Elevation[C]	Groundwater Elevation	Comments
SITE MONITORING WELLS								
WR-347A (MW-1A)	2/6/98	1415	96.10	Odor	Not Detected	2417.073	2320.97	Prior to development
	2/23/98	1000	96.48	Odor	Not Detected		2320.59	Prior to purging
	2/25/98	1708	96.51	Odor	Not Detected		2320.56	
	9/20/99	0830	95.43	Odor	---		2321.64	
	12/10/99	0945	95.01	Odor	---		2322.06	
	1/28/00	0854	95.66	Odor	---		2321.41	
	4/14/00	1135	96.31	Odor	---		2320.76	
	4/21/00	1319	96.37	Odor	---		2320.70	
	5/17/00	1225	96.57	Odor	---		2320.50	
	6/30/00	1650	96.75	Odor	---		2320.32	
	7/5/00	1404	96.76	Odor	---		2320.31	
	7/7/00	1356	96.75	Odor	---		2320.32	
	7/28/00	1650	96.85	Odor	---		2320.22	
WR-347B (MW-1B)	2/6/98	1420	202.20	No	NA	2417.078	2214.88	Prior to development
	2/23/98	1000	202.00	No	NA		2215.08	Prior to purging
	3/20/98	1350	201.84	No	NA		2215.24	
	9/20/99	0835	203.78	No	---		2213.30	
	1/28/00	0851	205.53	No	---		2211.55	
	4/14/00	1140	205.80	No	---		2211.28	
	4/21/00	1325	206.07	No	---		2211.01	
	5/17/00	0941	206.38	No	---		2210.70	
	6/30/00	1658	206.62	No	---		2210.46	
	7/7/00	1353	206.72	No	---		2210.36	
	7/28/00	1644	206.72	No	---		2210.36	
WR-345A (MW-2A)	2/6/98	0842	95.55	No	NA	2409.898	2314.35	Prior to development
	2/23/98	0845	95.37	No	NA		2314.53	Prior to purging
	2/25/98	1613	95.29	No	NA		2314.61	
	9/20/99	1800	94.52	No	---		2315.38	
	12/10/99	0925	93.14	No	---		2316.76	
	1/4/00	0915	93.56	No	---		2316.34	

TABLE 3. WATER LEVEL MEASUREMENTS – ARROYO CHICO PROJECT

Well ID	Date	Time	Depth to Water[A]	Odor?	Product Thickness[B]	Datum Elevation[C]	Groundwater Elevation	Comments
WR-345A (MW-2A)	1/28/00	0908	93.62	No	---	2409.898	2316.28	
	4/14/00	1050	94.38	No	---		2315.52	
	4/21/00	1245	94.51	No	---		2315.39	
	6/30/00	1154	95.43	No	---		2314.47	
	7/28/00	1627	95.68	No	---		2314.22	
WR-345B (MW-2B)	2/6/98	0837	197.35	No	NA	2409.813	2212.46	Prior to development
	2/23/98	0840	197.01	No	NA		2212.80	Prior to purging
	3/20/98	1408	196.66	No	NA		2213.15	
	9/20/99	1805	199.28	No	---		2210.53	
	12/10/99	0930	199.70	No	---		2210.11	
	1/4/00	0920	199.85	No	---		2209.96	
	1/28/00	0912	199.95	No	---		2209.86	
	4/14/00	1055	200.07	No	---		2209.74	
	4/21/00	1250	200.18	No			2209.63	
	6/30/00	1158	200.57	No	---		2209.24	
	7/28/00	1633	200.51	No	---		2209.30	
MISSION LINEN MONITORING WELLS								
MLR-1	3/20/98	1225	195.25	No	NA	2415.097	2219.85	
MLR-2	3/20/98	1300	195.67	No	NA	2414.052	2218.38	
MLR-3	3/20/98	1235	198.49	No	NA	2416.094	2217.60	
MLR-7	3/20/98	1245	200.52	No	NA	2419.338	2218.82	
MLS-4	2/25/98	1640	94.60	Product	0.39	2416.422	2321.82	
MLS-5	2/25/98	1630	89.41	Odor	Not Detected	2411.685	2322.28	Oily liquid on tip of probe
MLS-6	2/25/98	1653	94.38	Product	<0.01	2415.951	2321.57	

NOTES: Groundwater level measurements made by SCS using Solinst Model 122 Oil/Water Interface Meter or Solinst Water Level Indicator
NA = Not Applicable (no product detected)
--- = Oil/water interface meter was not used; however, no oily liquid was observed on tip of water level indicator
[A] Depth to groundwater measured at top of casing or sounding tube, in feet
[B] Thickness of floating product (depth measured at top of casing), in feet
[C] Surveyed by City of Tucson on March 31, 1998; datum elevation at north side of top of casing or sounding tube, as applicable.

TABLE 4. RESULTS OF PRELIMINARY RISK ASSESSMENT GROUNDWATER MODELING – PERCHED GROUNDWATER GRADIENT AT 0.006 FEET PER FOOT

Well No.*	Grid Values (meters)		1 Year	10 Year	25 Year	50 Year	70 Year	100 Year	200 Year	300 Year	400 Year	500 Year
	X	Y										
1	1,392	-304.5	0	0	0	0.00054	0.0063	0.038	0.26	0.43	0.51	0.54
2	1,436	65	0	0	0	0.00044	0.0055	0.034	0.23	0.41	0.50	0.52
3	1,109	174	0	0	0.00019	0.027	0.11	0.28	0.73	0.85	0.85	0.81
4	935	914	0	0	0.00000326	0.0028	0.021	0.087	0.40	0.57	0.62	0.63
5	500	848	0	0.00000015	0.0035	0.12	0.31	0.60	1.06	1.09	1.02	0.93

Table cells below each year value show the predicted concentration of tetrachloroethene (PCE) in mg/L (parts per million) after that time period has elapsed. Note that the Arizona Aquifer Water Quality Standard (AWQS) for PCE is 0.005 mg/L.

* Well 1: located 0.85 miles north-northwest of source
Well 2: located 0.87 miles north of source
Well 3: located 0.68 miles north-northeast of source
Well 4: located 0.79 miles northeast of source
Well 5: located 0.60 miles east-northeast of source

TABLE 5. RESULTS OF PRELIMINARY RISK ASSESSMENT GROUNDWATER MODELING – PERCHED GROUNDWATER GRADIENT AT 0.003 FEET PER FOOT

Well No.*	Grid Values (meters)		1 Year	10 Year	25 Year	50 Year	70 Year	100 Year	200 Year	300 Year	400 Year	500 Year
	X	Y										
1	1,392	-304.5	0	0	0	0.00053	0.0061	0.037	0.23	0.42	0.50	0.53
2	1,436	65	0	0	0	0.00044	0.0054	0.034	0.24	0.41	0.49	0.52
3	1,109	174	0	0	0.00018	0.026	0.11	0.28	0.72	0.84	0.84	0.80
4	935	914	0	0	0.00000323	0.0028	0.020	0.086	0.39	0.56	0.62	0.62
5	500	848	0	0.00000016	0.0035	0.12	0.30	0.60	1.05	1.08	1.01	0.93

Table cells below each year value show the predicted concentration of tetrachloroethene (PCE) in mg/L (parts per million) after that time period has elapsed. Note that the Arizona Aquifer Water Quality Standard (AWQS) for PCE is 0.005 mg/L.

* Well 1: located 0.85 miles north-northwest of source
Well 2: located 0.87 miles north of source
Well 3: located 0.68 miles north-northeast of source
Well 4: located 0.79 miles northeast of source
Well 5: located 0.60 miles east-northeast of source